# FISCAL YEAR 1983 DEPARTMENT OF ENERGY BUDGET REVIEW
## (Uranium Enrichment)

---

# HEARINGS

BEFORE THE

SUBCOMMITTEE ON

ENERGY RESEARCH AND PRODUCTION

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
NINETY-SEVENTH CONGRESS
SECOND SESSION

MARCH 30, 31, MAY 20, 1982

[No. 121]

VOLUME VI

Printed for the use of the
Committee on Science and Technology

U.S. GOVERNMENT PRINTING OFFICE
98-570 O
WASHINGTON : 1982

H701-21

## COMMITTEE ON SCIENCE AND TECHNOLOGY

DON FUQUA, Florida, *Chairman*

ROBERT A. ROE, New Jersey
GEORGE E. BROWN, Jr., California
JAMES H. SCHEUER, New York
RICHARD L. OTTINGER, New York
TOM HARKIN, Iowa
MARILYN LLOYD BOUQUARD, Tennessee
JAMES J. BLANCHARD, Michigan
TIMOTHY E. WIRTH, Colorado*
DOUG WALGREN, Pennsylvania
RONNIE G. FLIPPO, Alabama
DAN GLICKMAN, Kansas
ALBERT GORE, Jr., Tennessee
ROBERT A. YOUNG, Missouri
RICHARD C. WHITE, Texas
HAROLD L. VOLKMER, Missouri
HOWARD WOLPE, Michigan
BILL NELSON, Florida
STANLEY N. LUNDINE, New York
ALLEN E. ERTEL, Pennsylvania
BOB SHAMANSKY, Ohio
RALPH M. HALL, Texas
DAVE McCURDY, Oklahoma
MERVYN M. DYMALLY, California

LARRY WINN, Jr., Kansas
BARRY M. GOLDWATER, Jr., California
HAMILTON FISH, Jr., New York
MANUEL LUJAN, New Mexico
HAROLD C. HOLLENBECK, New Jersey
ROBERT S. WALKER, Pennsylvania
EDWIN B. FORSYTHE, New Jersey
WILLIAM CARNEY, New York
MARGARET M. HECKLER, Massachusetts
F. JAMES SENSENBRENNER, Jr., Wisconsin
VIN WEBER, Minnesota
JUDD GREGG, New Hampshire
RAYMOND J. McGRATH, New York
JOE SKEEN, New Mexico
CLAUDINE SCHNEIDER, Rhode Island
JIM DUNN, Michigan
BILL LOWERY, California

HAROLD P. HANSON, *Executive Director*
ROBERT C. KETCHAM, *General Counsel*
REGINA A. DAVIS, *Administrator*
GERALD E. JENKS, *Minority Staff Director*

## SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

MARILYN LLOYD BOUQUARD, Tennesee, *Chairman*

ROBERT A. ROE, New Jersey
RICHARD L. OTTINGER, New York
ROBERT A. YOUNG, Missouri
STANLEY N. LUNDINE, New York
RONNIE G. FLIPPO, Alabama
HAROLD L. VOLKMER, Missouri
HOWARD WOLPE, Michigan

MANUEL LUJAN, Jr., New Mexico
EDWIN B. FORSYTHE, New Jersey
BILL LOWERY, California
BARRY M. GOLDWATER, Jr., California
HAROLD C. HOLLENBECK, New Jersey

JOHN V. DUGAN, Jr., *Staff Director*
A. LEE WALLACE, *Minority Energy Director*
LOUIS VENTRE, Jr., *Counsel*
HARLAN L. WATSON, *Technical Consultant*

---

*On assignment to Budget Committee for 97th Congress.

# CONTENTS

## WITNESSES

March 30, 1982:

Page
- Hon. John H. Glenn, Jr., a Senator from the State of Ohio ..... 4
- Dr. Thomas A. Dillon, Principal Deputy Assistant Secretary for Nuclear Energy, U.S. Department of Energy; accompanied by William R. Voigt, Jr., Director of the Office of Uranium Enrichment and Assessment, U.S. Department of Energy ..... 16

Appendix I: Questions and answers submitted for the record ..... 47
- March 11, 1982 ..... 47
- April 21, 1982 ..... 173
- May 21, 1982 ..... 185

March 31, 1982:

- Richard L. Grant, president, Boeing Engineering and Construction, Southeast, Inc ..... 328
- Robert W. Clark, president, Goodyear Aerospace Corp ..... 362
- William H. Sutton, manager, commercial gas centrifuge program, AiResearch Manufacturing Co.; accompanied by Willis E. Sullivan, manager, Washington, D.C. office, The Garrett Corp ..... 379
- Dr. J. Robert Merriman, director, enrichment technology, Union Carbide Corp., nuclear division; accompanied by Richard L. Hoglund, deputy program manager, advanced isotope separation program, Union Carbide Corp., nuclear division; and William B. Arthur, engineer, advanced gas centrifuge program, Union Carbide Corp., nuclear division ..... 397

Appendix II: Questions and answers submitted for the record ..... 435

Appendix III: Additional material for the record ..... 446
- Statement of Hon. Howard M. Metzenbaum, a Senator from the State of Ohio ..... 446

May 20, 1982:

- William R. Voigt, Jr., Director, Office of Uranium Enrichment and Assessment, U.S. Department of Energy; accompanied by Dr. James E. Leiss, Chairman, Advanced Isotope Separation Process Evaluation Board and Associate Director, Office of High Energy and Nuclear Physics, Office of Energy Research, U.S. Department of Energy; and Dr. Norton Haberman, leader, technology development team, Office of Uranium Enrichment and Assessment, U.S. Department of Energy ..... 453
- Herman E. Roser, Assistant Secretary for Defense Programs, U.S. Department of Energy ..... 484

Appendix IV: Questions and answers submitted for the record ..... 501

Appendix V: Additional materials for the record ..... 521
- DOE news release dated April 30, 1982 announcing the selection of the atomic vapor laser isotope separation process for development and demonstration ..... 521
- Unclassified excerpts from the process evaluation board's assessment of the advanced isotope separation program, April 30, 1982 ..... 523
- Report of the Energy Research Advisory Board Study Group on advanced isotope separation, April 1982 ..... 532
- Report of the Energy Research Advisory Board Study Group on advanced isotope separation, November 1980 ..... 547

# FISCAL YEAR 1983 DEPARTMENT OF ENERGY BUDGET REVIEW

---

TUESDAY, MARCH 30, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
*Washington, D.C.*

The subcommittee met, pursuant to notice, at 1:32 p.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Bouquard (chairman of the subcommittee) presiding.

Present: Representatives Bouquard, Volkmer, and Hollenbeck.

Staff present: Harlan Watson, Lee Wallace, and Joyce Gross Freiwald.

Mrs. **Bouquard**. The subcommittee will come to order.

Good afternoon, ladies and gentlemen. The subcommittee meets today and tomorrow to consider the Department of Energy's uranium enrichment program. Today we will receive testimony from the Department of Energy on their budget request, and tomorrow we will hear from industry representatives.

The Department of Energy's uranium enrichment program includes management and operation of the Government's three gaseous diffusion plants located at Portsmouth, Ohio; Paducah, Ky.; and Oak Ridge, Tenn. The program is also funded for the development of the new gas centrifuge enrichment technology and construction of the gas centrifuge enrichment plant at Portsmouth, Ohio.

Research and development activities in advanced isotope separation technologies, which employ lasers and a plasma separation process, are also authorized under this program. Finally, it also includes the uranium resource assessment program.

With regard to the advanced isotope separation program, the subcommittee understands that the Department plans to recommend shortly that one of the processes be selected for acceleration to an engineering development phase. Because of the very sensitive nature of these deliberations, we agreed to delay substantive consideration of the AIS program until a process selection has been made. We plan to hold hearings on that program at a later date.

The committee has been a strong supporter of the Department of Energy's goal to be a reliable supplier of enrichment services to both domestic and foreign customers. Consequently, we have encouraged research on new enrichment technologies which offer significant savings in construction and operating costs, as well as advanced development and deployment of the most cost effective of these technologies.

Only by remaining at the forefront of technology can the United States expect to retain its position as the world's largest supplier of enrichment services in the face of the aggressive expansion of foreign enrichment capacity.

The Department's uranium enrichment program is self-supporting in the sense that charges to customers of enrichment, both domestic and foreign, cover completely the expenses for the operation of the enrichment plants and all research and development activities.

However, in spite of the fact that the program is self-sustaining, the committee will continue to vigorously exercise its oversight responsibility to insure that the program is managed properly.

I want to welcome back the Principal Deputy Assistant Secretary for Nuclear Energy, Dr. Tom Dillon, as well as another familiar face, Mr. Bill Voigt, Acting Director of the Office of Uranium Enrichment and Assessment. Tom and Bill, I am looking forward to hearing your testimony and responses to questions we have concerning the program.

Prior to the DOE testimony, we will be hearing from Senator John Glenn of Ohio.

It gives me great pleasure to welcome at this time Senator Glenn to this side of the Hill. Senator Glenn, as we are all aware, has long been an active and articulate and authoritative spokesman for the necessity for an aggressive Government stance with regard to research and development. We were especially appreciative of his editorial in the March 26 issue of Science entitled "Long-Term Economic RX: Research," which addresses the need for continuing strong support for R&D.

We also know that Senator Glenn has been one of the strongest supporters of the GCEP facility, and he will be addressing this project in his testimony, as well as revolving fund legislation and the United States-Australian joint venture proposal.

We are very happy to have you with us, and we certainly welcome, especially today, America's first man in orbit.

Senator Glenn, please proceed, and your article, without objection, will be made a part of the record.

[Material to be provided follows:]

26 March 1982, Volume 215, Number 4540

**SCIENCE**

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

*Science* serves its readers as a forum for the presentation and discussion of important issues related to the advancement of science, including the presentation of minority or conflicting points of view, rather than by publishing only material on which a consensus has been reached. Accordingly, all articles published in *Science*—including editorials, news and comment, and book reviews—are signed and reflect the individual views of the authors and not official points of view adopted by the AAAS or the institutions with which the authors are affiliated.

**Editorial Board**

*1982*: William Estes, Clement L. Markert, John R. Pierce, Bryant W. Rossiter, Vera C. Rubin, Maxine F. Singer, Paul E. Waggoner, Alexander Zucker

*1983*: Frederick R. Blattner, Bernard F. Burke, Charles L. Drake, Arthur F. Findeis, E. Peter Geiduschek, Glynn Isaac, Milton Russell, William P. Slichter, John Wood

**Publisher**
William D. Carey
*Associate Publisher*: Robert V. Ormes

**Editor**
Philip H. Abelson

**Editorial Staff**

*Assistant Managing Editor*: John E. Ringle
*Production Editor*: Ellen E. Murphy
*Business Manager*: Hans Nussbaum
*News Editor*: Barbara J. Culliton
*News and Comment*: Colin Norman (deputy editor), William J. Broad, Luther J. Carter, Constance Holden, Eliot Marshall, R. Jeffrey Smith, Marjorie Sun, John Walsh
*Research News*: Roger Lewin (deputy editor), Richard A. Kerr, Gina Kolata, Jean L. Marx, Thomas H. Maugh II, Arthur L. Robinson, M. Mitchell Waldrop
*Administrative Assistant, News*: Scherraine Mack; *Editorial Assistants, News*: Fannie Groom, Cassandra Watts
*Senior Editors*: Eleanore Butz, Mary Dorfman, Ruth Kulstad
*Associate Editors*: Sylvia Eberhart, Caitilin Gordon, Lois Schmitt
*Assistant Editors*: Martha Collins, Stephen Kepple, Edith Meyers
*Book Reviews*: Katherine Livingston, *Editor*; Linda Heiserman, Janet Kegg
*Letters*: Christine Gilbert
*Copy Editor*: Isabella Bouldin
*Production*: Nancy Hartnagel, John Baker; Rose Lowery; Holly Bishop, Eleanor Warner; Jean Rockwood, Leah Ryan, Sharon Ryan, Robin Whyte
*Covers, Reprints, and Permissions*: Grayce Finger, *Editor*; Geraldine Crump, Corrine Harris
*Guide to Scientific Instruments*: Richard G. Sommer
*Assistants to the Editors*: Susan Elliott, Diane Holland
*Membership Recruitment*: Gwendolyn Huddle
*Member and Subscription Records*: Ann Ragland

EDITORIAL CORRESPONDENCE: 1515 Massachusetts Ave., NW, Washington, D.C. 20005. Area code 202. General Editorial Office, 467-4350; Book Reviews, 467-4367; Guide to Scientific Instruments, 467-4480; News and Comment, 467-4430; Reprints and Permissions, 467-4483; Research News, 467-4321. Cable: Advancesci, Washington. For "Information for Contributors," write to the editorial office or see page xi, *Science*, 18 December 1981.
BUSINESS CORRESPONDENCE: Area Code 202. Membership and Subscriptions: 467-4417.

**Advertising Representatives**

*Director*: Earl J. Scherago
*Production Manager*: Gina Reilly
*Advertising Sales Manager*: Richard L. Charles
*Marketing Manager*: Herbert L. Burklund
Sales: New York, N.Y. 10036: Steve Hamburger, 1515 Broadway (212-730-1050); Scotch Plains, N.J. 07076: C. Richard Callis, 12 Unami Lane (201-889-4873); Chicago, Ill. 60611: Jack Ryan, Room 2107, 919 N. Michigan Ave. (312-337-4973); Beverly Hills, Calif. 90211: Winn Nance, 111 N. La Cienega Blvd. (213-657-2772); Dorset, Vt. 05251: Fred W. Dieffenbach, Kent Hill Rd. (802-867-5581).
ADVERTISING CORRESPONDENCE: Tenth floor, 1515 Broadway, New York, N.Y. 10036. Phone: 212-730-1050.

# Long-Term Economic Rx: Research

Research and development supported by both government and private sources transformed the United States into the dominant technological force in the world. But our commitment to maintain and extend the amount of research and development necessary to stay ahead in the technological race has slipped. Today, we are witnessing a wholesale retreat in the federal role in civilian research and development. This is manifest in the shrinking amount of research support for our universities, private nonprofit research laboratories, and national multi-program laboratories.

Over the past 15 years the proportion of the U.S. gross national product invested in research and development has steadily declined—dropping more than 20 percent since 1965. In the same period and by the same measure, the R & D investment in the Soviet Union climbed by 21 percent, in Japan by 27 percent, and in West Germany by 41 percent. In addition to this huge underinvestment in research and development, we are failing to produce the technically trained people that we need to sustain increases in productivity and to make advances in knowledge that will be the basis for our economic prosperity and national security in the coming decades. The intense demand for technically trained people has resulted in high salaries that are luring faculty and graduate students away from even our best universities. To complete this picture, there is mounting evidence that the research laboratories and instrumentation in American universities are rapidly becoming obsolete.

Let us examine the response of the Reagan Administration to this crisis in four specific areas: energy, space, science education, and the national laboratories.

Productive R & D efforts in industrial energy conservation, energy-efficient buildings, energy storage, and solar energy have been zeroed out in the President's fiscal 1983 budget, thus helping to ensure an unnecessarily prolonged U.S. dependence on oil from the Arabian Gulf. There is no evidence that any of these programs will be picked up by private industry.

Decisions on the space program are equally egregious. The Galileo Program is now the only remaining U.S. planetary program in development, and some of the older space probes may be turned off. Funds have been cut for a satellite to test new advances in communication. Aeronautics research has been cut at a time when the Europeans are challenging us with the development of the airbus and the Japanese are thinking of launching major forays into the international aircraft market.

In science education, the National Science Foundation's (NSF) request for extra funds to upgrade university laboratories has been zeroed out, and a 70 percent reduction has been forced on NSF in the science education budget. As for the national laboratories, Argonne National Laboratory officials say that 25 percent of their work force may be eliminated within the year. Brookhaven National Laboratory, Fermi National Accelerator Laboratory, NASA-Lewis Laboratory, and Jet Propulsion Laboratory have also suffered.

Several steps can be taken to meet the R & D crisis in America. We must provide stable, predictable funding for scientific and technological research; alleviate shortages of technical personnel; provide incentives for better university-industry collaboration; restore the science education program at NSF and improve science and mathematics education at the precollege level; and develop a coherent national science and technology policy that includes a larger role for the science and technology community in the making of such policy. If the Office of Science and Technology Policy cannot be sufficiently effective in this role, we should think seriously about creating a cabinet-level department of science and technology as a focal point for federal nondefense research activities. I urge the science community to help us get back on the right track.—John H. Glenn, *U.S. Senator (D–Ohio), Washington, D.C. 20510*

---

From a speech before the IEEE Conference on Technology Policy, 24 February 1982, Washington, D.C.

## STATEMENT OF HON. JOHN GLENN, A U.S. SENATOR FROM THE STATE OF OHIO

Mr. GLENN. Thank you, Madam Chairman. Thank you for the courtesy of granting my request to testify before this subcommittee on a most critical subject.

I have a longer statement. I would ask, if I might, that it be included in the record, and I will give a summarized version.

Mrs. BOUQUARD. Without objection, it will be made a part of the record at the conclusion of your oral presentation.

I think you are aware that we have a vote, and I know that you are very busy, and I was trying to expedite the proceedings.

Mr. GLENN. Fine. How much time do we have? I will go as rapidly as I can here.

This is a most critical subject, one that not only has profound economic implications for my home State of Ohio but is also of importance for the national security of the United States.

Since the inception of the atoms-for-peace program in 1953, the uranium enrichment program has played an important role in aiding the expansion of our nuclear industry and helping our nuclear nonproliferation effort. The uranium enrichment enterprise collected over $1.25 billion in revenues in fiscal 1981 and expects revenues during fiscal 1982 to exceed $1.8 billion. Nuclear enrichment services have helped us to reduce our enormous trade deficit over the years—more than $3 billion in total sales including some $539 million in fiscal 1981 alone. So it has played a vital role in the national security of the United States and the free world.

It is vitally important for the United States to remain a principal supplier of foreign enrichment needs for several reasons. First, we will be able to exert maximum influence on foreign users to cooperate in our nuclear nonproliferation objectives and, second, we will continue to reap the benefits of helping to reduce our balance of payments deficit. Third, we will be able to optimize the use of our available capacity in order to minimize the cost for all customers, both domestic and foreign.

Key to this strategy is the timely completion of the Portsmouth Gas Centrifuge Enrichment Plant, which will provide an additional 13.2 million SWU's upon its completion. GCEP will provide further assurance to our domestic and foreign customers that the United States is the most economical and most reliable source of enriched uranium.

GCEP is 20 times more energy efficient than the old gas diffusion process. Construction will avoid over $3.5 billion in construction of electric generating plants and save the energy equivalent of 1.5 billion barrels of oil over its lifetime relative to operating a similar capacity using diffusion technology.

In addition to these benefits, there is the matter of jobs. Some 10,000 people are employed in the operation, maintenance, and support of the 3 diffusion plants now. There are also more than 3,000 people engaged directly in the design and construction of the Portsmouth GCEP, and some 41 States have activities associated with this project.

DOE analysis has shown that it is desirable to build GCEP as quickly as possible; yet GCEP is under attack from certain quarters. We must modernize and expand our enrichment capacity or risk losing our position as a reliable supplier of competitively priced enrichment services.

Centrifuge technology has been well tested and is a result of over 20 years of research. To delay implementation of this technology in favor of advanced isotope separation, which has thus far been tested only on a laboratory scale, is to risk putting the United States behind its competitors.

The cost of the enrichment program, along with the rapidly changing domestic and foreign prospects for nuclear reactors and the business-type nature of the enterprise, calls for a financial system which provides for more management flexibility than is offered in the usual authorization and appropriations cycles.

This increased flexibility can be provided through establishment of a uranium enrichment revolving fund which should result in greater overall economy and efficiency. I have introduced a Senate bill, S. 350, to create such a fund, and I know that Representatives McEwen and Lujan have introduced similar bills on the House side.

The establishment of a revolving fund would aid marketing initiatives and would further U.S. nonproliferation objectives and improve the U.S. balance of payments. It would also provide some degree of stability to the uranium enrichment enterprise.

It is my view that the fund will aid our domestic industry as well as our competitive posture with respect to foreign uranium enrichment sales.

And, finally, I would like to just say a word about the current effort by the United States to bid on entering into a joint venture with Australia to build a uranium enrichment plant in that country. In connection with this proposal, DOE is examining various ways in which all or part of the nuclear enrichment enterprise could be converted to private ownership.

I wish to point out that private ownership of enrichment technology raises some serious questions involving national security and our nonproliferation efforts that require the most careful scrutiny. It is important that we obtain a clear understanding and commitment from the administration that GCEP will be completed in a timely fashion, regardless of the outcome of current United States-Australian discussions. This should be made a necessary condition for congressional support for such an international joint venture.

In conclusion, I will say simply that the United States needs both the GCEP program and a uranium enrichment revolving fund so that it can move forward with confidence into the next phase of our national nuclear enterprise, including the provision of additional energy and enhanced national security.

Thank you very much.

Mrs. **Bouquard**. Thank you very much, Senator Glenn. I am sorry I am going to have to rush, but we certainly do thank you for your valuable testimony.

The subcommittee will stand in recess for 10 minutes.

Mr. **Glenn**. Thank you very much.

[The prepared testimony of Senator Glenn follows:]

## Prepared Statement of Senator John Glenn

Madam Chairman:

Thank you for the courtesy of granting my request to testify before this Subcommittee on a most critical subject -- one that not only has profound economic implications for my home state of Ohio, but is of importance for the national security of the United States.

Madam Chairman, I know that you are more knowledgable than most about the value of our Uranium Enrichment Program to our nuclear effort over the past 30 years. Since the inception of the "Atoms-for-Peace" program first proposed by President Eisenhower in 1953, it has played an important role, both here and abroad, not only in aiding the expansion of our nuclear industry, but also in helping our nuclear nonproliferation effort.

Unlike most Government activities, the Uranium Enrichment Program provides a commercial service and represents a significant business operation. The program has been the sole supplier of all enrichment sevices to domestic civilian reactor customers since the Shippingport reactor started up in 1957 as the first U.S. power reactor. In addition, the program has supplied much of the Free World's enriched uranium needs as well.

The uranium enrichment enterprise collected over $1.25 billion in revenues in fiscal year 1981, and expects revenues during this fiscal year, FY 1982, to exceed $1.8 billion. Foreign sales of enrichment services have helped us to reduce our enormous trade deficit over the years -- more than $3 billion in total sales, including some $539 million in FY 1981 alone. We also have 295 contracts for enrichment services with U.S. and foreign utilities, extending beyond the year 2000, with a total value in the neighborhood of $75 billion.

In addition to these commercial activities, the Uranium Enrichment Program plays a vital role in support of national defense by supplying all defense requirements for highly enriched uranium including the requirements of the Nation's naval nuclear propulsion program. Furthermore, the program has provided all the highly enriched uranium used in our nuclear arsenal--a requirement that will escalate dramatically as we modernize our current stockpile of nuclear weapons with enhanced radiation and other advanced design warheads.

We have provided more than 330 million separative work units (SWU's) for U.S. and foreign civilian nuclear power facilities and for U.S. defense requirements, representing over 92 percent of the total Free World production. To have generated the equivalent electrical energy from this quantity of enriched uranium would have required nearly 27 billion barrels of oil--enough to suuply all our domestic needs for about 4 years and 8 months at our current rate of consumption.

It is vitally important for the United States to remain a principal supplier of foreign enrichment needs for several reasons. First, we will be able to exert maximum influence on foreign users to cooperate in our nuclear nonproliferation objectives. If nations continue to develop their own enrichment capability, then this could also be a source of nuclear weapons materials. Second, we will continue to reap the benefits of helping to reduce our balance-of-payments deficit. Third, we will be able to optimize the use of our available capacity in order to minimize the cost for all customers, both domestic and foreign.

## THE GCEP PROGRAM

Key to this strategy is timely completion of the Portsmouth GCEP which will provide an additional 13.2 million SWU's upon its completion. GCEP will provide further assurance to our domestic and foreign customers that the United States is the most economical and reliable source of enriched uranium. GCEP brings to the enriched uranium marketplace the prominent advantages of the centrifuge separation process technology including: (1) operation using only 5 percent of the power of the currently used gaseous diffusion process; (2) adaptability to construction in modular increments consistent with market expansion; and (3) the opportunity to develop and utilize even more advanced centrifuges which promise further effiency improvements when they are fully developed in the mid- to late 1980's.

As I just noted, relative to the currently used gaseous diffusion uranium enrichment process, GCEP is some 20 times more energy efficient--using only 5 percent of the electric power to produce an equivalent number of SWU's. Construction of GCEP will avoid over $3.5 billion in construction of electric generating plants and save the energy equivalent of 150,000 barrels of oil per day, or some 1.5 billion barrels over its lifetime, relative to operating a similar capacity using diffusion technology. GCEP leads to an incremental production unit cost 30 percent lower in 1982 dollars, and, with escalation, to a cost of only one-third that of the diffusion process in 1996.

In addition to these benefits, Madam Chairman, there is a matter of jobs. Today, some 10,000 people are employed in the operation, maintenance, and support of the three diffusion plants at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. There are also in excess of 3,000 people at all locations, engaged directly in the design and construction of the Portsmouth GCEP. These GCEP numbers do not include the subcontractors who supply the components, materials, and services -- some 5,000 to 7,000 people -- nor do they include the indirect activities induced not only in my State of Ohio, but also on the home states of the subcontractors as well, some 41 states in all.

Finally, Madam Chairman, DOE's recently completed Uranium Enrichment Operating Plan clearly shows that under a wide variety of assumptions regarding uranium enrichment demand, power cost escalation, and availability of new technology, it is desirable to build GCEP as quickly as possible.

For the base case operating plan developed to meet a mid-level civilian demand and low-level government demand, the DOE report states the following:

> "Accelerating the GCEP schedule...from the current schedule reduces the average DOE price of separative work over the 20-year period by about $1.60. The total out-of-pocket costs of producing enriched uranium (i.e., Total Enterprise Costs (TEC)) are reduced by $1,207 million ($388 million discounted). Customer costs of enriched uranium are correspondingly reduced by $822 million ($344 million discounted). Accelerating the GCEP schedule also results in electrical energy savings of almost 4,000 megawatt years.
>
> Conversely, delaying GCEP results in adverse economic consequences...A one-year delay in GCEP ...result(s) in a higher average DOE SWU price for separative work of $1.54/SWU over the next 10 years and $2.09/SWU over the following 10-year period. The TEC is increased by $953 million ($416 million discounted) and customer costs are increased by $969 million ($367 million discounted). Additional electrical energy consumption amounting to 3,175 megawatt-years also occurs.

Despite all its benefits, GCEP is under attack from certain quarters. Some clain that the dropping of nuclear commitments by American and foreign utilities makes timely completion of GCEP unnecessary; others say that advanced isotope separation using lasers is just around the corner, so why commit to centrifuge technology? In my view, this is a shortsighted approach to a serious problem. First, the DOE Uranium Enrichment Operating Plan shows that the demand is likely to be there at the time GCEP is scheduled to come on-line. In addition, however, we must remember that one of the few levers left to the U.S. in influencing the nuclear programs of other countries is our enrichment capacity and our ability to sell enrichment services at a reasonable price. If we do not modernize and expand our enrichment capacity, we risk losing our position as a reliable supplier of competitively-priced enrichment services. Finally, centrifuge technology has been well-tested and is the result of over 20 years of research. In addition, DOE has already had success in testing the next-generation centrifuges that will be available in time for installation in the third GCEP process building. Thus the claims made by DOE regarding operating costs and reliability appear to be completely justified. On the other hand, DOE admits that the information required for them to commit to an Advanced Isotope Separation plant will not be available before 1989. To say that we should delay implmentation of a well-tested technology in favor of one which has thus far been tested only on a laboratory scale is, once again, to risk putting the U.S. behind its competitors, some of whom are already using their own version of centrifuge technology. We should not forget that although nuclear demand may be low today, no-one can predict with certainty what the future may bring. The capacity of GCEP will be needed in this century, if present

DOE projections hold up.

## URANIUM ENRICHMENT REVOLVING FUND

I recognize the concerns that some have over the cost of this project. However, it is important to recognize that U.S. law provides for such costs to be eventually returned to the Treasury through appropriate pricing of services. That, along with the rapidly changing domestic and foreign prospects for nuclear reactors and the business-type nature of this enterprise calls for a financial system which provides for more management flexibility than is offered in the usual authorization and appropriations cycles.

This increased flexibility can be provided through establishment of a uranium enrichment revolving fund which should result in greater overall economy and efficiency. I have introduced a Senate bill, S. 350, to create such a fund, and I know that Representatives McEwen and Lujan have introduced similar bills on the House side. Among the advantages of such a fund would be the improvement of the United States' image as a world supplier of enrichment services and the blunting of foreign competitors' criticisms about the "unbusinesslike" nature of U.S. enrichment operations. The establishment of a revolving fund would thus aid in marketing initiatives, primarily international, and would further U.S. nonproliferation objectives and improve U.S. balance of payments.

Madam Chairman, in May 1980, Dr. Ruth Davis, DOE's Assistant Secretary for Resource Applications, requested that a group of experienced business executives be assembled to review the operation, financing, and management of the uranium enrichment enterprise. The review group, composed of distinguished individuals who had held top-level executive positions, was specifically asked to focus on the management activities to which sound business practices could be applied. Their recommendations, released on December 2, 1980, included support of a revolving fund:

> "If a revolving fund were established, the enrichment enterprise would be managed as a self-sufficient entity, generating adequate cash flow for operation and capital outlay. The enterprise would have an exceptionally strong borrowing base, should bond financing become necessary for major capital expansion projects. This financial flexibility would enable it to time purchases vis-a-vis receipts, manage case effectively, and employ other cost-saving techniques used by corporate management.
>
> Besides these financial advantages, the revolving fund would give the enterprise greater visibility among its domestic and overseas customers and among U.S. taxpayers..."

I wholeheartedly agree with the review panel's assessment and I believe that the revolving fund legislation will bring these benefits. In recognition of the continuing congressional interest in the enterprise, expenditures would be subject to limitations and directives that might be inserted into authorization and appropriation acts. Moreover, the Secretary of Energy could not acquire plant and capital equipment whose cost exceeds 5 percent of the total net book value of the uranium enrichment fixed assets or construct new enrichment capacity without express congressional authorization. In addition, obligations for plant and capital equipment which would increase expenditures to a level greater than 15 percent above that approved by Congress could not be made until Congress had been notified and a period of 30 days while Congress is in session had elapsed.

Madam Chairman, it is vitally important that some degree of stability be provided to the uranium enrichment enterprise at this time. Past cutbacks and stretchouts endured by the GCEP Program and rumors of additional attempts to cut back on the program in FY 83 are a subject of great concern at a time when the United States wishes to reestablish its position as a reliable supplier in the area of nuclear enrichment services and at a time when our nonproliferation efforts are seen in some quarters to be flagging. The revolving fund will bring a degree of stability to the enrichment enterprise that will make it less subject to budgetary whim.

In creating this revolving fund, I would not want to reduce or to make more difficult congressional oversight over the nuclear enrichment enterprise. Accordingly, the bill requires that comprehensive reports be sent to the Congress concerning the operation of the fund, DOE plans on enrichment activities for the future, the financial position of the fund, projections and statements of policy regarding tails assay, and projected uranium enrichment needs.

It is my view that the Uranium Enrichment Fund will aid our domestic industry as well as our competitive posture with respect to foreign uranium enrichment sales.

## THE U.S./AUSTRALIA JOINT VENTURE PROPOSAL

Finally, Madam Chairman, I would like to say a word about the current effort by the U.S. to bid on entering into a joint venture with Australia to build a uranium enrichment plant in that country. In connection with that effort, and in response to a directive issued by the President, DOE is examining various ways in which all or part of the nuclear enrichment enterprise could be converted to private ownership. It is not my intention here, to go into all the pros and cons of this activity. I do wish to point out, however, that private ownership of enrichment technology raises some serious questions involving national security and our nonproliferation effort that require the most careful scrutiny. Beyond that, there is the question of whether a U.S./Australian plant will end up competing with GCEP for future contracts. That, in itself, may not necessarily be bad as long as the projected demand holds up. In any case, however, it is important that we obtain a clear understanding and commitment from the Administration that GCEP will be completed in a timely fashion regardless of the outcome of current U.S./Australian discussions. This should be made a necessary condition for Congressional support for such an international joint venture.

In conclusion, Madam Chairman, I will say simply that the U.S. needs both the GCEP Program and a uranium enrichment revolving fund so that it can move forward with confidence into the next phase of our national nuclear enterprise, including the providing of additional energy and enhanced national security.

Thank you.

Mrs. BOUQUARD. The subcommittee will now come to order.

I do want to welcome back the Principal Deputy Assistant to the Assistant Secretary for Nuclear Energy, Dr. Tom Dillon, as well as another familiar face, Mr. Bill Voigt, who is Acting Director of the Office of Uranium Enrichment and Assessment. I am certainly looking forward to your testimony, and you all may proceed as you wish.

## STATEMENT OF DR. THOMAS A. DILLON, PRINCIPAL DEPUTY ASSISTANT SECRETARY FOR NUCLEAR ENERGY, U.S. DEPARTMENT OF ENERGY, ACCOMPANIED BY WILLIAM R. VOIGT, JR., DIRECTOR OF THE OFFICE OF URANIUM ENRICHMENT AND ASSESSMENT, U.S. DEPARTMENT OF ENERGY

Dr. DILLON. Thank you very much, Madam Chairman.

I am pleased to appear before the subcommittee to discuss the agency's uranium supply and enrichment activities. With your permission, I would like tc submit for the record a statement containing an overview of all our programs and a detailed discussion of our uranium enrichment program.

Mrs. BOUQUARD. Without objection, your statement will be made a part of the record at the conclusion of your oral presentation.

Dr. DILLON. Thank you.

A key element in our efforts to firmly establish the United States as a reliable supplier of nuclear fuel services is our uranium-enrichment program. The fiscal year 1983 budget for this program is about $2 billion, which is fully offset by revenues.

The Office of Uranium Enrichment and Assessment periodically estimates the domestic and non-U.S. nuclear electric-generating capacity that will be served by the U.S. enrichment complex.

Our latest estimates, made last summer, projected online worldwide nuclear power capacity to be served by the United States to be 137 gigawatts in 1985, 182 gigawatts in 1990, and 226 gigawatts in 1995.

As compared to our estimates of 5 years ago, the 1995 demand for uranium-enrichment services has decreased by about 25 percent. Our current projections indicate the capacity beyond what is available in the gaseous diffusion complex will be required in the 1990's.

The need for the gas centrifuge enrichment plant, GCEP, continues to be supported by the results of the Department's thorough analyses of the alternatives available to the enrichment enterprise. In all cases, continued construction of GCEP yields superior benefits, both to the Government and its customers, in terms of improved economics and production reliability.

Without GCEP, the United States will price itself out of the enrichment business. Even at reduced demand levels, the cost of production from GCEP will be significantly lower than production for the existing electricity-intensive gaseous diffusion plants.

The rapid deployment of enrichment technologies capable of reducing U.S. production cost is both a necessary and a prudent business decision. Our centrifuge technology is the most advanced, proven enrichment technology in the world and offers the United

States the opportunity to regain its leadership and market share in the international nuclear community.

The advanced isotope separation methods currently under development by the Department offer the promise of further market gains but must reach a higher stage of development before they can be counted on for production planning.

The current uranium-enrichment market is highly competitive, with a limited number of near-term sales opportunities, all of which are outside the United States. The U.S. position in the foreign market has declined from a 100-percent share in 1974 to about a 35-percent share today. A number of our customers have switched from the United States to EURODIF, URENCO, and the Soviet Union, and some new business has gone to these suppliers.

To meet this challenge, we have implemented an active marketing effort to effectively enhance the sales advantages of the U.S. uranium-enrichment program. We are simultaneously proceeding with cost-reduction activities at the existing enrichment production facilities, introducing the more economical gas centrifuge process, developing even more advanced technologies, and interacting more actively with our customers to respond to their needs.

An advanced enrichment technology, advanced isotope separation, or AIS, is being developed. AIS offers the potential advantage of further reductions in both capital costs and energy consumption, but it does not enjoy the same technological base as the centrifuge option. When successfully developed, the AIS process could provide new enrichment capacities in the mid-to-late nineties.

Selection of a single process for engineering development from among the three candidate processes will occur in fiscal year 1982, and progress toward the development module will continue during fiscal year 1983.

Because the priority work of the assessment element of our program has been completed, the assessment program is being phased out in fiscal year 1982 and will be terminated during fiscal year 1983. During fiscal year 1982, steps will be taken to complete projects underway and to put the very large data base in order for possible future use.

Reduction in force and termination of the operating contractor at Grand Junction will have to begin in fiscal year 1982 in order to meet the required notification periods and funding constraints. Funds requested for fiscal year 1983 are to complete program closeout activities.

This concludes my summary statement, Madam Chairman.

[The prepared testimony of Dr. Dillon follows:]

# STATEMENT OF THOMAS DILLON
PRINCIPAL DEPUTY ASSISTANT SECRETARY FOR NUCLEAR ENERGY
DEPARTMENT OF ENERGY
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH & PRODUCTION
COMMITTEE ON SCIENCE & TECHNOLOGY
March 30, 1982

Madam Chairman and Members of the Committee, I am pleased to appear before you today to continue discussion of our nuclear fission energy program. At the March 9, 1982, hearing before the Committee, Dr. Brewer submitted an overview of all our programs for the record and discussed the activities of the Breeder Reactor and Nuclear Fuel Cycle Programs. On March 16, 1982, I discussed our programs for Converter Reactor Systems, Nuclear Fuel Cycle other than Reprocessing, the Civilian Waste Management Programs, and Advanced Nuclear Systems. Today, I am accompanied by Bill Voigt, the Director of the Office of Uranium Enrichment and Assessment to discuss our programs for Uranium Enrichment.

## URANIUM ENRICHMENT

The goal of the Uranium Enrichment Program is to meet domestic and foreign utility and United States Government requirements for uranium enrichment services in the most economical, reliable, safe and environmentally acceptable manner possible.

The FY 1983 budget for the Uranium Enrichment Program is shown in Chart 1 by major program component. The FY 1983 request is $1,967,046,000 for authorization and appropriation offset by $2,032,700,000 in projected revenues. FY 1983 excess revenues of $65,654,000 are to be carried over and used to offset FY 1984 requirements.

The Uranium Enrichment Program consists of three subprograms: (1) Uranium Enrichment Activities; (2) Advanced Isotope Separation, and (3) Uranium Resource Assessment.

## PROJECTION OF URANIUM ENRICHMENT REQUIREMENTS

The Office of Uranium Enrichment and Assessment periodically estimates the domestic and non-U.S. nuclear electric generating capacity that will be served by the United States uranium enrichment complex.

Our latest estimates made last summer projected online worldwide nuclear power capacity to be served by the United States to be 137 gigawatts in 1985, 182 gigawatts in 1990 and 226 gigawatts in 1995.

## CHART 1

## URANIUM ENRICHMENT PROGRAM

| | Budget Authority (Dollars in Thousands) FY 1982 | Budget Authority (Dollars in Thousands) FY 1983 |
|---|---|---|
| Uranium Enrichment Activities | | |
| Gaseous Diffusion | | |
| Cascade Power | $ 802,000 | $ 904,000 |
| Other Operations and Support | 228,892 | 315,250 |
| Total Gaseous Diffusion | 1,030,892 | 1,219,250 |
| Gas Centrifuge | | |
| GCEP | 588,000 | 613,000 |
| Other Operations and Support | 87,216 | 94,500 |
| Total Gas Centrifuge | 675,216 | 707,500 |
| Program Direction | 3,019 | 3,100 |
| Total Uranium Enrichment Activities | $ 1,709,127 | $ 1,929,850 |
| Advanced Isotope Separation | 85,711 | 34,196 |
| Uranium Resource Assessment | 9,979 | 3,000 |
| Subtotal | 1,804,817 | 1,967,046 |
| Revenues | -1,830,200 | -2,032,700 |
| Revenues to be carried over to FY 1984 | 0 | 65,654 |
| Total, Uranium Enrichment Program | $ -25,383* | $ 0 |

*The net FY 1982 appropriation after revenues is $1 million. The number shown reflects comparability adjustments.

Domestic nuclear power capacity in these totals are 90 gigawatts in 1985, 122 gigawatts in 1990, and 140 gigawatts in 1995. The forecast is based on reactors currently operating or under construction. Our total forecast estimate is lower than projected in last year's testimony by 7 gigawatts in 1985, 9 gigawatts in 1990 and 6 gigawatts in 1995. The reduced estimate reflects additional delays and/or cancellations of nuclear power construction.

Separative work requirements for these gigawatt projections are determined from near-term contract information and standardized boiling water and pressurized water reactor models in the longer term. The requirements also reflect the leadtime required for processing enriched uranium from the time of withdrawal from the enrichment plants and insertion into the reactor. In addition, separative work is required to support Government programs such as the Naval Reactor program and other defense programs. These requirements are provided to us by the appropriate program offices.

## LONG-TERM STRATEGY

A long-term enrichment production strategy is developed to meet these requirements after considering a wide range of supply options. The strategy is chosen after considering economics, operational risks, and the flexibilities that are available to respond to higher or lower demand levels. In the short term, the strategy is to lower the operating levels of the gaseous diffusion complex, requiring power purchases below existing contract levels, and reduce inventories of enriched uranium. Even though this will require the Agency to pay capacity charges to its power suppliers for power not purchased, it remains the most economical way to operate in the long term. In FY 1983, the complex will operate at the same power levels as in FY 1982. These levels represent an acceptable level of risk of equipment failures from prolonged operations below plant design levels.

The long-term strategy is to continue design and construction of the Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio. The GCEP will initially provide an additional 2.2 million separative work units (SWU) of capacity by 1989. Capacity will be added in increments as dictated by demand, with completion of the full GCEP (eight process buildings) currently projected for 1994. This is the same schedule as was presented in the FY 1982 budget. Also, the output of the gaseous diffusion plants will be reduced in the mid-1990's by replacing some of the gaseous diffusion production with the less costly GCEP production. An advanced isotope separation process may be available for production in the mid-1990's providing further cost reductions by replacing gaseous diffusion capacity.

## UNITED STATES COMPETITIVE POSITION

The current uranium enrichment market is highly competitive with a limited number of near-term sales opportunities, all of which are outside of the United States. The United States position in the non-United States market has declined from a 100 percent share in 1974 to about a 35 percent share today. A number of our foreign customers have switched from the United States to EURODIF, URENCO and the Soviet Union, and some new business has gone to these suppliers. Today we face competition in the international market from suppliers with the following enrichment capacities:

Foreign Suppliers of Uranium Enrichment Services and Their Enrichment Capacity

| Supplier | Capacity (Millions of SWU/Year) |
|---|---|
| USSR | 3 to 4 available for export now |
| URENCO | 0.6 operating; 2.0 committed; 3.0 possible by 1990 |
| EURODIF | 10.8 capacity, production will be at a lower level |
| JAPAN | 2.0 possible by 1990 |
| BRAZIL | no current capacity; 0.2 possible by 1985 |
| AUSTRALIA | 1.0 possible by 1995 and 3.3 in the year 2000 timeframe |

To date, the total value of sales lost by the United States to its competitors is nearly $1.5 billion. During FY 1981 alone, the United States lost three enrichment contracts worth about $800 million over the lifetime of the nuclear reactors involved. This continues to be of great concern to us and we must reverse this trend.

Price has become a very important sales consideration to enrichment customers and our competitors have met this need by offering price guarantees equal to or slightly less than the United States by pricing on an incremental basis. Our competitors' strategy has proven quite successful in weakening the United States greatest market advantage. Last year, the United States enjoyed a price advantage of $30 to $50 per SWU. Since then the United States price increased by $20, the competitors have reduced their price, and fluctuating exchange rates have further reduced our competitors' prices. Our competitors' strategy, which was the primary reason the United States lost the three contracts in FY 1981 noted previously, has placed them in a very strong position to capture new sales opportunities in Taiwan and Mexico worth more than $1.3 billion.

Our competitors' ability to offer contracts with price, quantity, and timing provisions tailored to meet individual customer preferences has also given them an edge. We are not able to offer contracts on this basis due to the nondiscriminatory requirements legislated in Section 161v of the Atomic Energy Act of 1954, as amended.

To meet this challenge, we have implemented an active marketing effort to effectively enhance the sales advantages of the United States uranium enrichment program. Specifically, the uranium enrichment program is taking steps to minimize the current and future selling price by reducing operating costs at the gaseous diffusion plants, constructing GCEP, and pursuing more advanced and economically attractive technologies.

These efforts are beginning to produce results. We have recently signed a letter of intent with Egypt for the sale of one new uranium enrichment contract (to cover a 1,000 megawatt nuclear reactor) and an increased sales commitment of an existing contract (from 660 megawatts to 960 megawatts). From this action, we expect to realize about $20 million in additional annual revenues starting in the early 1990's, with a lifetime sales value in excess of $500 million.

Improvement in the United States marketing posture is expected to improve the probability of obtaining new sales in Taiwan, Switzerland, Mexico, Egypt and Yugoslavia. These sales are estimated to be worth more than $70 million in annual revenues starting in the early 1990's.

By maintaining and expanding our sales base, the United States will continue to realize significant benefits in terms of domestic employment, balance of payments and contribution to nuclear policies abroad.

## URANIUM ENRICHMENT ACTIVITIES

The budget for Uranium Enrichment Activities as shown in Chart 1 is described in two major program activities: (1) Gaseous Diffusion and (2) Gas Centrifuge.

## GASEOUS DIFFUSION

The United States presently enriches uranium to the desired U-235 product assay levels in its gaseous diffusion plants located at Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky. In these plants, the United States enriches customer-provided natural uranium in the U-235 component for a fee which recovers the cost of providing the services.

As indicated on Chart 1, $1,219,250,000 is requested for operation of the gaseous diffusion complex. The three gaseous diffusion plants will operate at a power level of 2,660 megawatts in FY 1983 and produce about 9.8 million SWU. The FY 1983 operating level is consistent with long-term enrichment strategy and represents an acceptable risk of process equipment failures from prolonged operations below plant design levels.

The 2,660 megawatt power level is substantially below the 4,548 megawatts we are contractually committed to purchase under existing contracts with the three power suppliers. Consequently, we are contractually required to pay about $151,000,000 (Tennessee Valley Authority (TVA)--$129,000,000, and Ohio Valley Electric Company (OVEC)--$22,000,000) in capacity charge payments in FY 1983 for power under contract that will not be purchased. If the Agency purchased power at the contractually committed level of 4,548 megawatts, the power budget would be increased by $394,000,000 from $904,000,000 to $1,298,000,000.

We are continuing discussions with the power suppliers in an attempt to reduce the capacity charge payments for power not purchased. As in the past, the success of these negotiations depends on the ability of our power suppliers to transfer contract power not purchased by the Agency to other customers. Relief from OVEC for FY 1983 is heavily contingent upon the level of economic activity in the Midwest. Relief from TVA is unlikely at this time because of the surplus generating capacity within TVA's own system, as well as within neighboring systems.

The total FY 1983 cascade power budget, including $151,000,000 in capacity charges, is $904,000,000. This is an increase of $102,000,000 over the FY 1982 budget and represents increases in the cost of power purchased due to higher coal costs and increased capacity charges for power not purchased.

Funding requested for diffusion operations, process and long range technical support, supporting services, capital equipment and construction is $315,250,000. The major increases over the FY 1982 budget are for common use stores and miscellaneous revenue expenses that were previously budgeted in the Agency's administration appropriation, and for escalation of costs. On a comparable basis and assuming an 8 percent cost escalation, the FY 1983 budget request is actually less than the FY 1982 budget. This reduction is the result of a deliberate effort by the Office of Uranium Enrichment and Assessment to minimize costs. In turn, SWU price increases will also be minimized. The requested funds are the minimum amounts needed to operate the plants; to replace equipment that has exceeded its useful life; to properly maintain the plants; and to comply with environmental and safety standards.

## GAS CENTRIFUGE

The FY 1983 budget request contains $613,000,000 for the construction of the Gas Centrifuge Enrichment Plant (GCEP) and $94,500,000 for other centrifuge activities.

The GCEP will provide an additional 2.2 million SWU per year of capacity by 1989. This GCEP capacity can be further increased to 3.3 million SWU per year through retrofit with advanced gas centrifuge machines now in development. Utilizing advanced centrifuge machines, GCEP will be completed by adding capacity in blocks of 1.65 million SWU sequentially as dictated by demand up to a total of 13.2 million SWU per year. Completion of the full GCEP is currently projected for 1994. This is the same schedule as was presented in the FY 1982 budget.

The construction of GCEP, authorized in FY 1976, provides the only legal basis for reopening the United States order books. In addition, GCEP represents the only additional technology which has demonstrated a production reliability sufficient to guarantee that the U.S. can, in fact, meet additional sales commitments from new contracts. This ability to contract with the foreign and domestic utilities is necessary to maintain a United States position as a major world supplier of uranium enrichment services.

Projections of the long-term United States uranium enrichment market share show that additional capacity is needed to meet demand in the 1990's. Strategic analyses indicate that GCEP should be used to meet this demand because GCEP provides the most economical, currently available means of supplying enrichment services. The GCEP is expected to produce separative work at a lower cost than gaseous diffusion production. This will lower the price of enrichment services which will lower the total cost of enriched uranium for customers. Lowered prices, in turn, will improve the United States competitive position in the international marketplace. The availability of GCEP also provides the opportunity to displace more costly gaseous diffusion production.

Our analysis also shows that the incremental cost of completing the full eight-process-building plant is cost competitive with the advanced isotope separation processes when an adjustment is made to reflect the uncertainties of the advanced processes. If successful, an advanced isotope separation process will provide an alternative for lower cost production in future plants and further displacement of the gaseous diffusion plants.

GCEP is making excellent progress and is on schedule with the total estimated cost (adjusted for escalation) holding constant. Project momentum continues to build as the physical construction at the site near Portsmouth, Ohio, progresses. Process Building No. 1 is enclosed, the floor modules for the centrifuge machines are installed, and contracts have been let for the process piping, electrical, heating and ventilation systems. Site preparation and rough grading for all eight process buildings is complete. The fire station, central receiving warehouse, mobile equipment garage, the administration building, and several supporting facilities are finished. Work is well underway on the Recycle/Assembly building, electrical substations, and the process support building. Through FY 1982, $1,585,520,000 has been authorized and $1,539,845,000 appropriated, with estimated costs of $1,197,531,000 against a total estimated project cost of $6,950,000,000 in FY 1983 dollars. Design of the entire complex is over 72 percent complete with six of the nine major architect engineers having essentially finished their design efforts. Three centrifuge machine manufacturers have constructed manufacturing facilities using corporate funding in Ohio and Tennessee. All of the centrifuge manufacturers are in production and have delivered centrifuge machines that have passed the 2,000-hour evaluation test. This demonstrates the capability of United States industry to manufacture the baseline centrifuge.

The FY 1983 request for other centrifuge operations and support on Chart 1 includes the funds to proceed with operational startup plans and procedures to support operation of the first production units of the GCEP, continuation of the advanced gas centrifuge development program, capital equipment and construction. The FY 1983 budget request for these activities is $94,500,000 or an increase of $7,284,000 over FY 1982. GCEP startup activities are increasing by $7,600,000 and developmental activities declining $316,000. Assuming 8 percent escalation, the centrifuge development activities are declining about $6,877,000. This decline reflects a maturing of the centrifuge program.

The Advanced Gas Centrifuge (AGC) program is designed to provide a production centrifuge with separative capacity 50 percent greater than the baseline centrifuge. The advanced technology is an extrapolation of the technology already developed and will be achieved through a modest increase in speed and improved flow management. Development of this design is currently underway and about one-half of the performance increase has already been achieved in early test centrifuges. The advanced technology objectives are reasonable and the probability of this technical achievement is high. We expect that the 50 percent increased performance machine will be available for installation in the third GCEP process building and can be retrofitted into process buildings 1 and 2.

## ADVANCED ISOTOPE SEPARATION

The primary objective of the Advanced Isotope Separation (AIS) program is to develop a technology capable of producing enriched uranium at a cost of less than $40 per SWU in FY 1981 dollars. In addition to low overall cost, AIS offers a process with a low capital investment requirement and low energy consumption. Successful development and deployment of AIS may help replace power intensive diffusion plants or provide new enrichment capacity.

The budget request for the AIS program in FY 1983 is $34,196,000 in budget authority compared to $85,711,000 in FY 1982. Operation within this reduced budget is possible by selecting one of the three processes after all essential technical data have been compiled and evaluated for advancement to the engineering development and demonstration phase, and completely terminating in FY 1982 all activities associated with the two nonselected processes.

During the past year, excellent progress has been made on the plasma, atomic vapor, and molecular AIS processes. The primary emphasis in FY 1982 is on the operation of the preprototype testbed systems that are providing a major portion of the data needed for identifying the engineering uncertainties associated with scaling the AIS technologies. This information, along with offline component tests and economic analysis, provide input for both process selection and future engineering development.

In FY 1983 the Agency will upgrade and continue operation of the selected AIS preprototype system and initiate prototype engineering of components by subsystem integration efforts. This approach will provide initial development of the specifications required for the near-production-scale components for the Development/Demonstration Module.

## URANIUM RESOURCES

Assessments of United States resources indicate that at least 1 million short tons of $U_3O_8$ could be recovered at a forward cost of $30 per pound $U_3O_8$ from reserves and probable potential resources; uranium recovered at a cost of $30 per pound $U_3O_8$ would be expected to require prices averaging about $45 per pound. Although the average delivery price for uranium was $31 per pound in 1981, and spot prices were about $25 per pound, uranium priced at $45 per pound should result in nuclear power plant operating costs that continue to be lower than the operating costs in coal-fired power plants in most areas of the United States.

The current forecast range of domestic nuclear power growth indicates that as much as 195 gigawatts could be operating by the year 2000. The 1 million short tons of $U_3O_8$ should be able to support these reactors into the next century.

## STATE OF THE DOMESTIC URANIUM PRODUCING INDUSTRY

The United States uranium industry faces a difficult situation. The industry has overbuilt production capacity and must reduce production in order to be in better balance with demand. The adjustments must be made primarily because of the reductions in uranium demand and falling prices resulting from nuclear power reactor construction delays, cancellations, and lack of new reactor orders. This situation has caused some producers extreme economic hardship and will cause continued economic difficulties over the next few years. On the other hand, some producers reported a profitable year in 1981. After the adjustments are completed, the companies that remain as domestic uranium producers should comprise a viable industry. Other producers can enter the industry as the uranium demand grows.

In 1980, the United States uranium industry produced a record 21,850 short tons of $U_3O_8$. In 1981, the industry produced about 19,000 tons, and in 1982, we estimate a production of about 15,500 tons. Most of this production will be used directly to supply reactor needs, although some of the uranium is projected to be added to utility inventories. In the mid-1980's, domestic utilities are projected to have an average annual requirement (which includes purchase commitments plus uncontracted needs) of about 15,500 tons. Thus, requirements should be in approximate balance with current production. As reactors now under construction begin operation, we expect the domestic utilities' annual requirement for uranium to increase to about 20,000 tons in 1990 and to about 30,000 tons in 1995.

The reduction from the record production level of 21,850 tons to today's production resulted from some mines and mills closing or curtailing production. Employment in the uranium industry has dropped from an all time high of 22,000 in 1979 to around 15,000 at the end of 1981.

Surface drilling for uranium exploration and ore deposit development reached an all time record of 47 million feet drilled in 1978, but has dropped to an estimated 14 million feet in 1981. The outlook for industry exploration work is uncertain at present.

Restrictions on the enrichment of foreign uranium for domestic end-use are being removed in steps according to a plan announced in 1974 by the Atomic Energy Commission in accordance with Section 161v of the Atomic Energy Act of 1954, as amended. The plan allowed initial use of foreign uranium in 1977 limited to 10 percent of an enrichment services customer's feed deliveries to the Agency. The allowable percentages increased to 15 percent in 1978, 20 percent in 1979, 30 percent in 1980, 40 percent in 1981, and 60 percent in 1982. The plan increases the percentage to 80 percent in 1983 and in 1984 there would be no established limit.

In the 5 years from 1977 to 1981, domestic use of foreign uranium has been low as United States buyers have preferred to buy United States uranium. Over the 5 years, only 8 percent of the uranium delivered for enrichment by domestic customers was of foreign origin, compared with an allowable weighted average of 22 percent. In 1981, the actual deliveries of foreign-origin uranium for enrichment have been 9 percent of total domestic deliveries, well below the allowable 40 percent. Although there will be continued and probably increasing use of foreign uranium in the United States, we expect United States buyer preference for domestic uranium to continue.

## URANIUM RESOURCE ASSESSMENT PROGRAM

Because the priority work of the assessment program has been completed, and because of the projected adequacy of the uranium resources to support the industry's needs into the next century, the program is being phased out in FY 1982 and will be terminated in FY 1983.

The goals of the assessment program were to assess and expand the nuclear fuel resource base of the United States; reduce uncertainties about the extent, availability and economics of domestic and foreign nuclear fuel resources; and make available to industry resource information and technology for use in the discovery and production of uranium resources. The program has estimated uranium reserves based on proprietary industry data, analyzed uranium supply, assessed potential uranium resources, developed improved methodology and technology for resource identification, and assessed and supported international activities to estimate the world uranium resource base.

During FY 1982, steps will be taken to complete projects underway and to put the very large data base in order for possible future use. Reduction in force and the termination of the operating contractor at Grand Junction will have to begin in FY 1982 in order to meet required notification periods and funding constraints. Funds requested for FY 1983 are to complete the program closeout activities.

Dr. **Dillon**. With your permission, I would like to show a brief film highlighting some of the progress we have made at the Portsmouth project on GCEP, and then Mr. Voigt and I will be available for any questions you might have.

Mrs. **Bouquard**. Thank you for your testimony, Dr. Dillon, and we look forward to seeing your film at this time.

[Film shown.]

Mrs. **Bouquard**. Thank you.

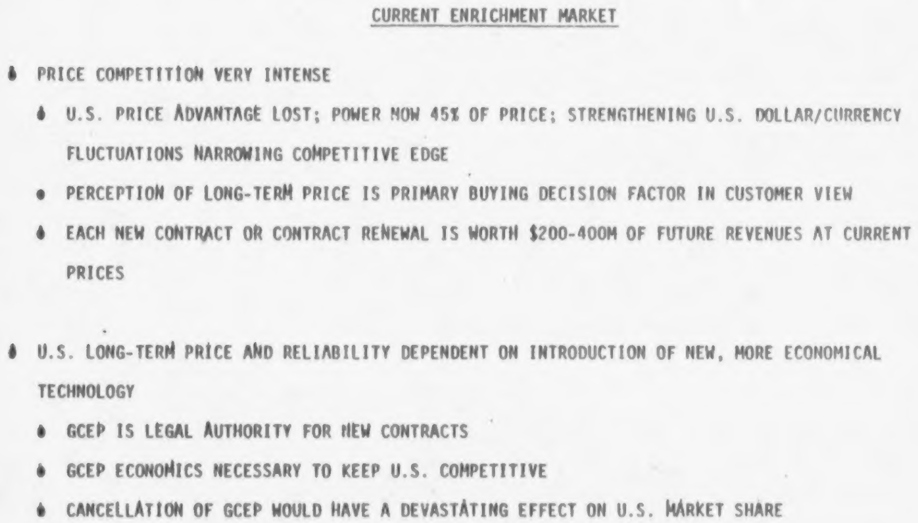
Please proceed with your testimony, Mr. Voigt.

Mr. **Voigt**. I have no prepared testimony, Madam Chairman.

In regard to the areas of particular interest to the subcommittee, we have brought some slides and would be pleased to show them if you would care to get into those areas at this time.

Mrs. **Bouquard**. That is very kind.

[Slide 1 shown.]



CURRENT ENRICHMENT MARKET

- PRICE COMPETITION VERY INTENSE
  - U.S. PRICE ADVANTAGE LOST; POWER NOW 45% OF PRICE; STRENGTHENING U.S. DOLLAR/CURRENCY FLUCTUATIONS NARROWING COMPETITIVE EDGE
  - PERCEPTION OF LONG-TERM PRICE IS PRIMARY BUYING DECISION FACTOR IN CUSTOMER VIEW
  - EACH NEW CONTRACT OR CONTRACT RENEWAL IS WORTH $200-400M OF FUTURE REVENUES AT CURRENT PRICES
- U.S. LONG-TERM PRICE AND RELIABILITY DEPENDENT ON INTRODUCTION OF NEW, MORE ECONOMICAL TECHNOLOGY
  - GCEP IS LEGAL AUTHORITY FOR NEW CONTRACTS
  - GCEP ECONOMICS NECESSARY TO KEEP U.S. COMPETITIVE
  - CANCELLATION OF GCEP WOULD HAVE A DEVASTATING EFFECT ON U.S. MARKET SHARE

Slide 1

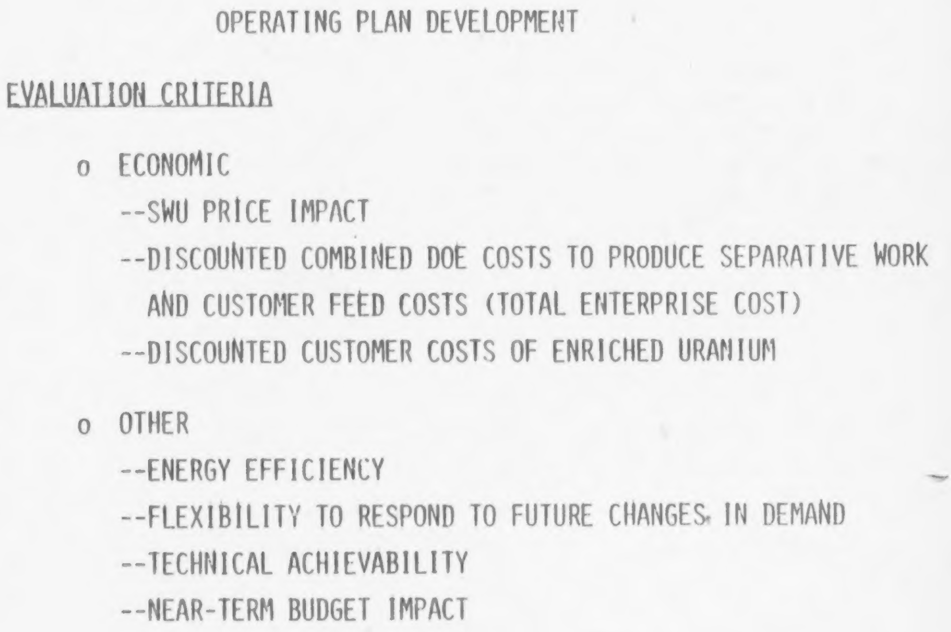
Mr. **Voigt**. First, turning to the current enrichment market, price competition is very intense. This slide depicts some of the factors involved in the loss of the U.S. price advantage in this market. The price differential between the United States and the foreign competition has lessened due to a number of reasons including the strengthening of the U.S. dollar as contrasted to the French franc and the German deutsche mark.

Our contractholders consider long-term SWU prices as the principal decision factor, in selecting an enrichment supplier. Each new contract or contract renewal is worth $200 million to $400 million of future revenues at current prices.

In terms of what GCEP means to the program, the U.S. long-term price and reliability are dependent upon the introduction of new and more economical technology. As the chairman is well aware, the GCEP will be required to meet contract commitments and to enter into new contracts.

The economics of GCEP are necessary to keep us competitive. In my view and the view of the Department, the cancellation of GCEP would have a devastating effect on the U.S. market share and result in loss of billions of dollars to the U.S. economy.

[Slide shown.]



OPERATING PLAN DEVELOPMENT

EVALUATION CRITERIA

- o ECONOMIC
  - --SWU PRICE IMPACT
  - --DISCOUNTED COMBINED DOE COSTS TO PRODUCE SEPARATIVE WORK AND CUSTOMER FEED COSTS (TOTAL ENTERPRISE COST)
  - --DISCOUNTED CUSTOMER COSTS OF ENRICHED URANIUM
- o OTHER
  - --ENERGY EFFICIENCY
  - --FLEXIBILITY TO RESPOND TO FUTURE CHANGES IN DEMAND
  - --TECHNICAL ACHIEVABILITY
  - --NEAR-TERM BUDGET IMPACT

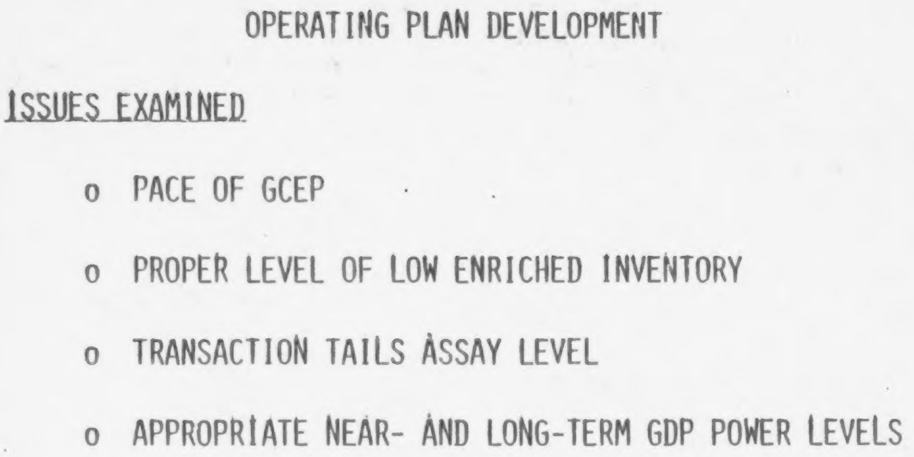
SLIDE 2

In developing our long-term, enrichment-operating plan, the evaluation criteria that are used are primarily economics. We look at the SWU price impact, the discounted combined DOE cost to produce separative work as well as the customers' cost. That is what we call a total enterprise cost. Third, we look at the discounted customer cost for enriched uranium.

In developing this operating plan, the other considerations that we enter into are: Energy efficiency, flexibility to respond to future changes in demand, technical achievability, and the near-term budget impact.

Next slide, please.

[Slide 3 shown.]



OPERATING PLAN DEVELOPMENT

ISSUES EXAMINED

- o PACE OF GCEP
- o PROPER LEVEL OF LOW ENRICHED INVENTORY
- o TRANSACTION TAILS ASSAY LEVEL
- o APPROPRIATE NEAR- AND LONG-TERM GDP POWER LEVELS

SLIDE 3

In developing this operating plan, the issues that we examined were the pace of GCEP, the proper levels of our low enrichment inventory, transaction tails assay, and the appropriate near- and long-term gaseous diffusion plant power levels.

We run many, many cases in examining these issues, Madam Chairman. This particular comparison is for the midcivilian nuclear power growth, and a low Government demand, that being the demand placed upon us by the naval propulsion program as well the weapons program. Also in this particular case, we ran a 3-percent power escalation above normal escalation rates.

Now, although we used 3 percent as the highest number, our power actually has escalated a lot higher than that. It has been rising about 17 percent a year.

Among the cases that we looked at were maintaining the GCEP on schedule, accelerating the GCEP, a 1-year delay in GCEP, a 2-year delay, a 4-year delay, only proceeding with two buildings, and not proceeding at all. In terms of SWU price and discounted cash flow, as is indicated in this chart, all criteria indicate that we should proceed with a full accelerated GCEP program.

[Slide shown.]

Just to give an indication, we have run sensitivity analyses around the demand portion. In this particular case, we looked at a low civilian demand and a low Government demand escalating power at 3 percent and 1.5 percent, and it still indicates that GCEP should be pursued as rapidly as we can.

[Slide shown.]

Table 1
Comparison of Economics (83$)
Mid-Civilian - Low Government Demand
High (3%) Power Cost Escalation

| | Full GCEP Accelerated | "Base" Full GCEP No Delay | GCEP 1 Yr. Delay | GCEP 2 Yr. Delay | GCEP 4 Yr. Stretch | 2 Building GCEP | No GCEP |
|---|---|---|---|---|---|---|---|
| 1983-1992 Avg. Price ($/SWU) | 143.36 | 144.94 | 146.48 | 147.91 | 147.49 | 148.68 | 143.70 |
| 1993-2002 Avg. Price ($/SWU) | 135.04 | 136.64 | 138.73 | 140.77 | 141.72 | 157.36 | 156.37 |
| **Total Enterprise Cost** | | | | | | | |
| Undiscounted | 136,697M | 137,904M | 138,857M | 139,904M | 140,031M | 147,286M | 149,802M |
| Discounted @ 10% | 60,079M | 60,467M | 60,883M | 61,276M | 61,234M | 62,360M | 61,936M |
| **Customer Cost** | | | | | | | |
| Undiscounted | 158,822M | 159,644M | 160,613M | 161,536M | 161,758M | 166,785M | 165,168M |
| Discounted @ 10% | 65,461M | 65,795M | 66,162M | 66,502M | 66,510M | 67,736M | 66,830M |
| **GDP Power Usage** 1983-2002 (MW-Yr.) | 97,001 | 100,949 | 104,124 | 107,272 | 108,187 | 125,868 | 130,160 |

Note: M = millions of dollars

The economic results indicate that we should build GCEP as rapidly as possible, that even if AIS achieves full success on its earliest possible schedule, the GCEP production is economically competitive and permits additional diffusion capacity replacement. Third, GCEP is far more economical than preproduction, even if uranium prices are very low.

Again, we have looked at the separative work inventory, and have tried to minimize the inventory that we carry because this in turn decreases our SWU price. We are now maintaining only a 90-day inventory ahead of our demand, and we have eliminated the 5 million SWU bank that we were carrying under the auspices of the Nuclear Nonproliferation Act.

We have also done some sensitivity analyses around tails assay which indicate that we should maintain a two-tenths tails assay.

This is representative of the yearly type of analysis that we do in arriving at business judgments as to what we should do in the enrichment enterprise.

Mrs. BOUQUARD. Thank you very much.

I think we have another vote. I will make the vote and then we will come back for questions, if that is agreeable.

The committee stands in recess.

[Recess taken.]

Mrs. BOUQUARD. We will resume our hearings, and again I apologize for our delay.

We are happy that Congressman Volkmer is with us. He is one of our more faithful members of the committee. We certainly do appreciate his interest. Harold, do you have questions at this time?

Mr. VOLKMER. No questions.

Mrs. BOUQUARD. We will proceed with some questions.

Dr. Dillon, you noted a decrease in the power capacity projections. Would you translate for us these power projections to the projected SWU capacity needed to meet the level of capacity?

Dr. DILLON. Those numbers that I gave you that reflect this added up to 226 gigawatts by 1995. That corresponds to a SWU requirement of 31 million SWU's per year in the operating plan.

In 1990, it would be 25 million SWU; in 1985, 24 million SWU.

Mrs. BOUQUARD. We have had a number of powerplant deferrals in the past 6 months. Would this change your projections if these were taken into account? How would you handle this, Tom?

Dr. DILLON. Very slightly. During the latter part of 1981 and the early part of 1982, nine plants that had been in our operating plan have been canceled. So there would be a reduction of those nine plants. So instead of 226, it would be more accurately 215. But that kind of change in the numbers is not going to have a very radical effect on the conclusions that Bill presented.

Mrs. BOUQUARD. You were stating projections for a midrange case, weren't you?

Dr. DILLON. That is right. Bill also showed a low-range case, which was the second slide he showed. Even in that case, which would be 197 gigawatts, we still had strong economic incentives to go forward with GCEP.

So, whereas the cancellations that have occurred in the latter part of last year and the early part of this year would bring us from 226 down to 215, it is still a lot higher than the 197 case

Table 5
Comparison of Economics (83$)
Low-Civilian - Low Government Demand

| | High (3%) Power Cost Escalation | | Low (1.5%) Power Cost Escalation | |
|---|---|---|---|---|
| | Full GCEP No Delay | No GCEP | Full GCEP No Delay | No GCEP |
| 1983-1992 Avg. Price ($/SWU) | 152.60 | 147.80 | 148.58 | 142.12 |
| 1993-2002 Avg. Price ($/SWU) | 137.11 | 160.83 | 126.77 | 139.68 |
| **Total Enterprise Cost** | | | | |
| Undiscounted | 118,508M | 131,987M | 114,960M | 125,139M |
| Discounted @ 10% | 53,248M | 54,459M | 52,017M | 52,383M |
| **Customer Cost** | | | | |
| Undiscounted | 140,439M | 146,030M | 136,931M | 13[illegible],388M |
| Discounted @ 10% | 58,363M | 59,275M | 57,232M | 57,326M |
| **GDP Power Usage** | | | | |
| 1983-2002 (MW-Yr.) | 81,751 | 122,320 | 81,751 | 122,320 |

Note: M = millions of dollars

which is the low demand case. So we are still in a very strong incentives positions for completion of GCEP.

Mrs. BOUQUARD. What are some of the problems and the weaknesses that you have when you try to forecast these demands and when you are performing market surveys?

Dr. DILLON. Well, right now, we do our estimating based on firm plant commitments and contracts, and they are always subject to a utility's deferral or to a cancellation. There is really no good way to predict that because it reflects a very complex decisionmaking process that they have to go through, weighing the need for power and the utility's service area, the financial condition of the utility, the overall condition of the economy.

So those things are really very difficult for us to predict. What we have not put into these forecasts, and for pretty obvious reasons, is the possibility of new requirements coming up. Now, if there were to be a strong recovery in the economy, a strong demand for electricity, it is very conceivable that, particularly in the 1995 time frame, there could be additional markets for separative work. Those have not been included, either.

Mrs. BOUQUARD. Again, you reflected a midrange case in all the projections that you made?

Dr. DILLON. Yes.

Mrs. BOUQUARD. What is the impact of the weapons and defense-related requirements upon this projection? Do these requirements impact the demand for SWU's?

Dr. DILLON. They do. We have a defense requirement for separative work. It is not extremely large, but it is a factor that enters into our plan. We have included in there the requirements for defense purposes.

Mrs. BOUQUARD. What is the projected cost for GCEP in 1983 dollars, in fully escalated dollars? Do you have that, Bill?

Dr. DILLON. Bill, do you want to respond?

Mr. VOIGT. $6.9 billion in 1983 dollars; $10.1 billion in fully escalated dollars.

Mrs. BOUQUARD. What is it fully escalated?

Mr. VOIGT. $10.1 billion.

Mrs. BOUQUARD. How much of the projected cost is the cost of centrifuges and how much would you say is construction?

Mr. VOIGT. Forty percent of the cost is centrifuge related, and about 27 percent is construction related. The other percentages are other procurements such as the recycle assembly and other areas ancillary to it, other than the machine itself.

Mrs. BOUQUARD. I think you are aware that Senator Glenn and Congressmen Lujan and McEwen have introduced revolving fund legislation to shield the uranium enrichment enterprise from the normal authorization and appropriation processes. What is the administration's position on revolving fund legislation?

Dr. DILLON. Well, certainly, we have looked at the concept of a revolving fund and the effect that it would have on the whole enrichment enterprise, and there are certain advantages that would accrue to the enrichment operation.

Mrs. BOUQUARD. Would you please outline some of the advantages and some of the weaknesses if we did convert to a revolving fund.

Dr. DILLON. The basic advantage is that the revolving fund concept would allow us to proceed with the enrichment enterprise in a fashion more analogous to a normal business. It would allow us to use the funds within the overall enterprise in a way that would, I think, more closely parallel the way it would occur if it were a private venture.

In fact, the administration's position is that we would like to explore the possibility of seeing if the private sector would be able to take over all or part of the enrichment activities and carry them out as an actual business.

That is the reason the administration has held back in terms of support for the revolving fund concept, because it does want to pursue the option of seeing if some of this activity can be turned over to the private sector.

Bill, do you want to comment?

Mr. VOIGT. I think the main thing, to echo Tom's remarks, Madam Chairman, is that it allows you to more soundly base your decisions on a longer period of time rather than on an annual budget year, and I think that is the real distinct advantage of it.

Mrs. BOUQUARD. Let us turn to something we have heard much about lately, fair value pricing, We want to understand what this term basically means.

Mr. VOIGT. Basically, fair value pricing, Madam Chairman, was, at the outset, proposed in conjunction with the Nuclear Fuel Assurance Act, which was legislation to privatize enrichment and to insure that we did not have a dual-tiered pricing system, one being full-cost recovery, the other commercial.

It has been our estimate that if we were to go to fair value pricing, it would increase our costs as much as 30 percent.

Mrs. BOUQUARD. This would really take us out of a competitive market, wouldn't it?

Mr. VOIGT. Yes.

Mrs. BOUQUARD. Thank you very much.

One other comment that I wanted to touch on this afternoon, and that is the impact of the applications of the international safeguards on GCEP.

Dr. DILLON. Madam Chairman, I think that the safeguards provisions that we are going to be recommending are not expected to have an adverse impact in terms of protecting our sensitive technology. We do feel they would give advantages in terms of increased control of safeguarding nuclear material and other centrifuge activities.

Bill, do you want to comment?

Mr. VOIGT. At the present time, we have what we call a Hexapartite Safeguard Committee, which is comprised of the United Kingdom, West Germany, the Netherlands, Japan, Australia, and the United States, all of whom expect to have centrifuge capacity within their jurisdictions. In fact, there is a meeting in Australia this week discussing various modes of safeguarding of centrifuge enrichment plants.

We have announced to other countries, again at this meeting, that we will permit some access to our process buildings, provided that there is reciprocal access provided to the other centrifuge plants, but with the full thrust of not disclosing any of our sensitive technology.

Mrs. BOUQUARD. So our sensitive technology is safeguarded?

Mr. VOIGT. Yes.

Mrs. BOUQUARD. Thank you very much. I certainly appreciate you gentlemen being with us today and those in the audience who participated in our hearings, and I do again want to apologize for our extensive delays this afternoon.

The hearings will be adjourned. The subcommittee will meet again in the morning at 9 o'clock in room 2318 to continue the hearings on the enrichment program.

[Whereupon, at 2:49 p.m., the subcommittee recessed, to reconvene on Wednesday, March 31, 1982, at 9 a.m.]

[Appendix I, questions and answers submitted for the record follows:]

# APPENDIX I

## QUESTIONS AND ANSWERS SUBMITTED FOR THE RECORD

DON FUQUA, FLA., CHAIRMAN

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD BOUQUARD, TENN.
JAMES J. BLANCHARD, MICH.
DOUG WALGREN, PA.
RONNIE G. FLIPPO, ALA.
DAN GLICKMAN, KANS.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
RICHARD C. WHITE, TEX.
HAROLD L. VOLKMER, MO.
HOWARD WOLPE, MICH.
BILL NELSON, FLA.
STANLEY N. LUNDINE, N.Y.
ALLEN E. ERTEL, PA.
BOB SHAMANSKY, OHIO
RALPH M. HALL, TEX.
DAVE MCCURDY, OKLA.
MERVYN M. DYMALLY, CALIF.

LARRY WINN, JR., KANS.
BARRY M. GOLDWATER, JR., CALIF.
HAMILTON FISH, JR., N.Y.
MANUEL LUJAN, JR., N. MEX.
HAROLD C. HOLLENBECK, N.J.
ROBERT S. WALKER, PA.
EDWIN B. FORSYTHE, N.J.
WILLIAM CARNEY, N.Y.
MARGARET M. HECKLER, MASS.
F. JAMES SENSENBRENNER, WIS.
VIN WEBER, MINN.
JUDD GREGG, N.H.
RAYMOND J. MCGRATH, N.Y.
JOE SKEEN, N. MEX.
CLAUDINE SCHNEIDER, R.I.
JIM DUNN, MICH.
BILL LOWERY, CALIF.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

HAROLD P. HANSON
EXECUTIVE DIRECTOR

PHILIP B. YEAGER
ROBERT C. KETCHAM
REGINA A. DAVIS
MARTHA KREBS
GEORGE S. KOPP
JOHN V. DUGAN, JR.
THOMAS H. MOSS
DARRELL R. BRANSCOME
ANTHONY C. TAYLOR
THOMAS P. GRUMBLY

GERALD E. JENKS
MINORITY STAFF DIRECTOR

March 11, 1982

Dr. Shelby T. Brewer
Asst. Secty. for Nuclear Energy
U.S. Department of Energy
Washington, DC 20585

Dear Dr. ~~Brewer~~: Shelby

The Subcommittee is evaluating the Department's Fiscal Year 1983 budget request for the Uranium Enrichment Activities and Advanced Isotope Separation (AIS) Technology program. To facilitate this evaluation, I am enclosing a copy of questions the Subcommittee has concerning the program. I hope this additional information can be made available to us by March 24, 1982.

Thank you for your assistance.

Sincerely,

Jack

JOHN V. DUGAN, JR.
Staff Director
Subcommittee on Energy Research
and Production

JVD:Wma
Enclosure

## GASEOUS DIFFUSION OPERATIONS AND SUPPORT

1. (a) Provide detailed objectives, justifications, funding levels, and milestones for each of the expenditure categories cited in the FY 1983 Congressional Budget Request of $168,000,000 for diffusion operations (i.e., wages, employee benefits, supplies and expenses associated with plant operations, etc.).

(b) Provide a detailed breakdown of FY 1982 expenditures for diffusion operations estimated to total $154,700,000, and justifications of increases in the FY 1983 request.

2. (a) Provide detailed objectives, justifications, funding levels, and milestones for each of the activities to be funded by the FY 1983 request of $18,000,000 for process and long range support.

(b) Provide a detailed breakdown of FY 1982 expenditures for process and long range technical support activities estimated to total $17,075,000, and justifications of increases in the FY 1983 request.

3. (a) Provide detailed objectives, justifications, funding levels, and milestones for each of the activities to be funded by the FY 1983 request of $26,500,000 for gaseous diffusion supporting services.

(b) Provide a detailed breakdown of FY 1982 expenditures for gaseous diffusion supporting activities estimated to total $25,125,000, and justifications of increases in the FY 1983 request.

4. Provide detailed justification, funding levels, and a priority listing for the FY 1983 request of $21,600,000 for gaseous diffusion operations and support capital equipment.

5. Why is $7,000,000 required for Project 83-N-401 in FY 1983, since the program funding will be spread over 6 fiscal years (FY 1983 - FY 1988)? Provide an alternative request which accounts for this long project funding schedule.

6. Provide a detailed description of work, cost breakdown of the estimated $12,940,000 in "special facilities" required at Oak Ridge, Tennessee for Project 83-N-402, and a milestone schedule.

7. Provide a list of projects together with a detailed cost breakdown, justification, and priority listing for the FY 1983 request of $18,000,000 for General Plant Projects planned to be funded in Project 83-N-404.

8. Why is $8,000,000 requested for Project 83-N-405 in FY 1983, since the program funding will be spread over a period of five fiscal years (FY 1983 - FY 1987)? Provide an alternative request which accounts for this long project funding schedule. Provide a description of the utilities and related costs to be installed for $12,200,000.

9. Provide detailed justifications and milestones for Project 82-R-413, as well as a rationale for the FY 1983 budget request of $20,900,000. Also provide an alternative funding request which accounts for the long project funding schedule.

10. Provide detailed justifications and milestones for Project 82-R-416 and Project 81-R-506, environmental protection and safety improvements at gaseous diffusion plants.

11. Provide the Subcommittee with a copy of the December 1981 uranium enrichment operating plan.

## GASEOUS CENTRIFUGE OPERATIONS AND SUPPORT

12. (a) Provide detailed objectives, justifications, funding levels, and milestones for each of the activities to be funded by the FY 1983 request of $73,400,000 for the gas centrifuge process development and demonstration task categories (i.e., Basic Studies, Materials Development, Development Facility Operations, Process Equipment Development, Baseline Machine, and Advanced Machine Development).

(b) Provide a detailed breakdown of FY 1982 expenditures for gas centrifuge process development and demonstration estimated to total $76,000,000 and justifications of increases in the FY 1983 request.

13. Provide the detailed operating plans, including FY 1982 and FY 1983 funding levels for the following test facilities: 1) the Advanced Equipment Test Facility, 2) the Component Preparation Laboratories, 3) the Technology Test Facility, and 4)

the Centrifuge Plant Demonstration Facility.

14. (a) Provide detailed objectives, justifications, funding levels, and milestones for each of the activities to be funded by the FY 1983 request of $12,800,000 for gas centrifuge supporting services.

(b) Provide a detailed breakdown of FY 1982 expenditures for gas centrifuge supporting services activities estimated to total $5,200,000 and justifications for increases in the FY 1983 request.

15. Provide detailed justification, funding levels, and a priority listing for the FY 1983 request of $3,800,000 for gas centrifuge operations and support capital equipment.

16. Why is $4,500,000 required for Project 82-R-418 in FY 1983? Why can't the funds be provided over a period of two or more years?

17. Provide the Subcommittee with the latest update of the following information with regard to Project 76-8-G, the Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio:

(a) Principal DOE prime contracts;

(b) Manpower projection (15 years) by function (i.e., government, support contractors, A&Es, construction, operation and machine manufacture);

(c) Manpower status;

(d) DOE/ORO staffing, planned and actual;

(e) Status of construction and procurement awards;

(f) Construction contracts awarded by PAO;

(g) Major UCC-ND GCEP subcontract awards to date;

(h) TEC savings derived from systems engineering;

(i) TEC by percent of total project (i.e., by functional activity and by buildings and improvement);

(j) Financial status--planned and actual to date and planned and actual cumulative to date, and planned in FY 1982 and FY 1983;

(k) Actual and planned construction awards in FY 1982 and FY 1983.

(l) Actual and planned procurement awards in FY 1982 and FY 1983;

(m) Latest summary schedule;

(n) Actual and planned percent project completion in FY 1982 and FY 1983;

(o) Cumulative cost and percent schedule variance;

(p) A&E design status;

(q) Operating contractor design status;

(r) Summary procurement schedule for centrifuge machines and balance of plant;

(s) Construction summary schedule, construction/procurement schedule, and off-site technical support facilities summary schedule by WBS category.

18. Assume a decision was made today to limit the scope of GCEP to two process buildings, rather than eight process buildings as planned. How much would the FY 1983 request of $613,000,000 be reduced? In other words, how much is included in the GCEP request for all activities beyond the first two process buildings?

19. Evaluate the impact on GCEP of FY 1983 budget levels $25 million, $50 million, $75 million, and $100 million below the $613,000,000 request. In other words, evaluate the impact on GCEP of FY 1983 budget levels of $588 million, $563 million, $538 million and $513 million.

20. What is the fully-escalated cost of a two-process-building GCEP, a three-process-building GCEP, a four-process-building GCEP, a five-process-building GCEP, a six-process-building GCEP, a seven-process-building GCEP, and an eight-process-building GCEP? What is the cost of each of these cases in FY 1983 dollars?

21. Provide data comparing projected SWU production costs from the 2.2 million SWU increment of GCEP with the SWU costs from the gaseous diffusion plants.

22. Provide documentation supporting DOE's case for an appropriate GCEP introduction strategy, given continued reductions in nuclear capacity growth projections and the possibility of a viable advanced isotope separation enrichment technology being demonstrated by the end of the decade and operationally available by the mid-1990s.

## ADVANCED ISOTOPE SEPARATION (AIS) TECHNOLOGY

23. Provide a detailed description of the AIS process selection methodology.

24. When does DOE plan to announce the selection of one of the processes for engineering development?

25. What criteria are being used by DOE to evaluate the AIS processes and what are the relative weights being attached to each of the criterion?

**Department of Energy**
**Washington, D.C. 20585**

MAR 26 1982

Mr. John V. Dugan, Jr.
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Dugan:

Enclosed are the answers to the questions you submitted on March 11, 1982, pertaining to the Uranium Enrichment Activities and Advanced Isotope Separation (AIS) Technology program.

If I can be of further assistance, please contact me.

Sincerely,

for J P Theneault
Shelby T. Brewer
Assistant Secretary
for Nuclear Energy

Enclosure

## QUESTIONS & ANSWERS

COMMITTEE ON SCIENCE AND TECHNOLOGY

Subcommittee on Energy Research and Production

URANIUM ENRICHMENT APPROPRIATION
Office of Uranium Enrichment
and Assessment

REFERENCE: Letter dated March 11, 1982
John V. Dugan, Jr. to
Dr. Shelby T. Brewer

Question 1.a. Provide detailed objectives, justification, funding levels and milestones for each of the expenditures categories cited in the Congressional Budget Request of $168,000,000 for diffusion operations (i.e. wages, employee benefits, supplies and expenses associated with plant operations).

b. Provide a detailed breakdown of FY 1982 expenditures for diffusion operations estimated to total $154,700,000 and justification of increases in the FY 1983 request.

Answer 1.a.& b. The objective of the diffusions operations account is to operate the three gaseous diffusion plants in a safe, efficient and environmentally acceptable manner while meeting the planned requirements for separative work (9.8 million SWU in FY 1982 and FY 1983). The breakout of the costs expected to be incurred in this account in fiscal years 1982 and 1983 are shown in the attached tables.

The FY 1983 increases in direct operating categories, operations, maintenance, utilities and support are less than FY 1982 when adjusted for escalation. This is a direct result of efforts to reduce program costs and keep the price of separative work competitive. The only real budget increases in FY 1983 are a result of budgeting for common use stores and miscellaneous revenue expense categories. Both of these categories of expenses were funded in the Departmental Administration appropriation in FY 1982.

(Millions of Dollars)

FY 1982

| | Direct Labor | Fringe Benefits | Supplies | All Other Expenses | Total |
|---|---|---|---|---|---|
| Cascade Operations ........... | 14.8 | 4.0 | 3.7 | 14.6 | 37.1 |
| Maintenance .................. | 16.2 | 6.1 | 5.0 | 17.1 | 44.4 |
| Utilities .................... | 8.0 | 2.1 | 12.3 | 14.4 | 36.8 |
| Production Support ........... | 12.6 | 3.3 | 2.4 | 12.5 | 30.8 |
| Process Spares Inventory ..... | | | | 0.5 | 0.5 |
| Common Use Stores Inventory .. | | | | 0.0 | 0.0 |
| Revenue Expenses* ............ | | | | 0.0 | 0.0 |
| Reroofing .................... | | | | 5.1 | 5.1 |
| Total Diffusion Operations .. | 51.6 | 15.5 | 23.4 | 64.2 | 154.7 |

FY 1983

| | Direct Labor | Fringe Benefits | Supplies | All Other Expenses | Total |
|---|---|---|---|---|---|
| Cascade Operations ........... | 16.4 | 4.5 | 3.8 | 13.3 | 38.0 |
| Maintenance .................. | 17.3 | 6.7 | 5.9 | 15.1 | 45.0 |
| Utilities .................... | 9.3 | 2.6 | 14.6 | 15.5 | 42.0 |
| Production Support ........... | 13.9 | 3.8 | 2.6 | 11.6 | 31.9 |
| Process Spares Inventory ..... | | | | 0.0 | 0.0 |
| Common Use Stores Inventory .. | | | | 3.9 | 3.9 |
| Revenue Expenses* ............ | | | | 6.3 | 6.3 |
| Reroofing .................... | | | | 0.9 | 0.9 |
| Total Diffusion Operations .. | 56.9 | 17.6 | 26.9 | 66.6 | 168.0 |

* Primarily Packaging, and Handling Charges

Question 2.a. Provide detailed objectives, justifications, funding levels, and milestones for each of the activities to be funded by the FY 1983 request of $18,000,000 for process and long range technical support.

Answer 2.a. The process and long-range technical support program is necessary to ensure continued efficient and reliable operation of the gaseous diffusion plants while meeting all safety and environmental requirements. The program is cost effective as technical, operational and health/ environmental benefits derived from the effort exceed program costs. The process and long range technical support program can be broken down into these missions. The objectives and justification for each mission are:

Mission I - Achieve CIP/CUP Capacity.

- Assure continued production of high quality barrier for the CIP/CUP.
- Optimize and document the benefits of CIP/CUP through operations analysis studies.

This mission will be completed in FY 1983.

Mission II - Support Operations and Maintain Production Capability

- Assure the highest possible production capability of installed barrier.
- Assure reliable long-term operation of process equipment and auxiliary systems.
- Assure reliable plant instrumentation and control systems.
- Preserve critical and unique barrier technologies, skills, and capabilities.
- Perform materials and chemistry studies in support of long-range productions goals.
- Perform operations analysis, system management, and planning studies in support of production goals.

Mission III - Meet Environmental, Health and Safety Needs

- Provide technology as required for future environmental, health, and safety line item projects.
- Provide environmental, health, and safety support for plant operations.

Representative milestones and funding for each mission for FY 1983 are:

Mission I - $120,000

- Completion of optimization and documentation of the CIP/CUP benefits; prepare final "report card" on CIP/CUP.

Mission II - $15,525,000

- Monitor and evaluate FY 1983 schedules for maintaining on-stream barrier performance. Issue schedules for FY 1984.
- Investigate the aging of barrier.
- Issue updated compressor and seal failure forecasts.
- Complete assessment of impact low power operations on cooling towers.
- Complete dynamic analysis operability assessment of Portsmouth tails withdrawal facility and make apropriate recommendations for improved operability and reliability.
- Report on investigations of reactions of $UF_6$ and coolant mixtures.
- Complete in-service evaluation of replacement compressor shaft shim stacks.
- Investigate the kinetics of formation, dissociation, and reaction of uranium products.

Mission III - $2,355,000

- Complete criteria specifying technology for uranium and technetium removal from vent streams for an FY 1985 line item project.
- Specify best available technology economically achievable for pollution control of specific liquid wastes.

Question 2.b. Provide a detailed breakdown of FY 1982 expenditures for process and long range technical support activities estimated to total $17,075,000, and justification of increases in the FY 1983 request.

Answer 2.b. A breakout of the FY 1982 budget by mission is shown below:

FY 1982

PROCESS AND LONG RANGE TECHNICAL SUPPORT

| | |
|---|---|
| Mission I - | $ 640,000 |
| Mission II - | $14,015,000 |
| Mission III - | $ 2,420,000 |
| TOTAL FY 1982 BUDGET - | $17,075,000 |

The FY 1983 budget request reflects a real dollar decline when compared to the FY 1982 budget adjusted for escalation.

The process and long range technical support program has recently completed a "consolidation" effort. This effort was designed to review the program from the bottom up and to eliminate low priority activities and unnecessary duplication among the three sites.

As a result, the current and long range budgets for the process and long range technical support program represent the minimum level of effort required to adequately support the gaseous diffusion plants.

Question 3.a. Provide detailed objectives, justifications, funding levels, and milestones for each of the activities to be funded by the FY 1983 request of $26,500,000 for gaseous diffusion supporting services.

b. Provide a detailed breakdown of FY 1982 expenditures for gaseous diffusion supporting activities estimated to total $25,125,000 and justifications of increase in the FY 1983 request.

Answer 3.a. & b. The objectives of the Supporting Service budgets for the gaseous diffusion plants is to provide the "non-operating" support functions that are required to keep a gaseous diffusion plant running in an efficient manner. These functions include: preparation and handling of feed materials, recovery of the large amounts of uranium generated in equipment decontamination prior to maintenance work, surveillance of facilities in standby status to prevent deterioration of expensive equipment, the costs of interplant shipments of intermediate assay uranium feeds, storage and handling of enriched product and tails materials, engineering studies for capital projects, etc., planning studies to set short- and long-term operating plans and day-to-day plant optimizations, and customer-related activities necessary to support marketing seminars, meetings, and missions. The non-uranium and all other activities category provides a variety of other supporting service such as maintenance (non-city roads and grounds) and part of the Oak Ridge Operations guard force contract. This account also includes the standby costs for plant facilities that are not being maintained on standby, specifically, for uranium enrichment related reasons, and miscellaneous costs that does not fit into the other categories. The funding levels for each of the categories for fiscal years 1982 and 1983 are shown in the following table.

| | B/A $ Thousands | |
|---|---|---|
| | FY 1982 | FY 1983 |
| Production of Cascade Feed ... | $ 2,103 | $ 400 |
| Recovery of Diffusion Scrap .. | 2,506 | 4,160 |
| Shutdown and Standby ......... | 630 | 890 |
| Transportation & Security Shipments .................. | 750 | 1,000 |
| Warehousing .................. | 2,110 | 2,850 |
| Special Engineering Studies .. | 4,900 | 4,700 |
| Special Planning Studies ..... | 7,549 | 7,050 |
| Marketing Activities ......... | 300 | 300 |
| Non-Uranium Enrichment and All Other Activities ............ | 4,277 | 5,150 |
| Total .................... | $25,125 | $26,500 |

When escalation from FY 1982 to FY 1983 is taken into consideration, the FY 1983 costs are less than in FY 1982. The only significant changes are in the production of cascade feed and recovery of diffusion scrap categories. The lower cascade feed costs in FY 1983 represents a projected decreased requirements for handling non-$UF_6$ uranium feed materials. The increase in diffusion scrap recovery costs in FY 1983 is due to full operation of a new biodenitrification facility that will start up in FY 1982 to reduce nitrate levels in plant discharges. The increase in the warehousing account is needed to cover costs of moving tails storage cylinders to new storage areas. The other categories are essentially the same level of effort in both years.

Question 4. Provide detailed justification, funding levels, and a priority listing for the FY 1983 request of $21,600,000 for gaseous diffusion operations and support capital equipment.

Answer 4. As we indicated in the budget submission, the gaseous diffusion plants have a backlog of about $35 million worth of equipment that has exceeded its normal service life and approximately $13 million exceeds normal service life each year. The capital equipment request in FY 1983 anticipate replacing about $12.9 million worth of equipment, adding about $7.5 million worth of critical new equipment and another $1.2 million for process development equipment. It is difficult to set meaningful priorities within these broad categories at this time; actual purchases will greatly depend on the contingencies and conditions that exist in FY 1983. However, our request is based on the following estimates:

| | Thousands of Dollars |
|---|---|
| Replacements | |
| Process equipment ........... | 5,430 |
| Shop equipment .............. | 3,620 |
| Heavy mobile equipment ...... | 1,170 |
| Motor vehicles .............. | 1,610 |
| Utilities, communications, laboratory, medical and office equipment ........... | 590 |
| Miscellaneous ............... | 455 |
| Subtotal ....... | 12,875 |
| Additions | |
| Operations .................. | 2,625 |
| Administrative and general support .................... | 2,940 |
| Automatic data processing ... | 1,950 |
| Subtotal ...... | 7,515 |
| Process development ........... | 1,210 |
| TOTAL .... | 21,600 |

These totals are approximately evenly divided between three large, equipment intensive gaseous diffusion plants.

Question 5. Why is $7,000,000 required for Project 83-N-401 in FY 1983, since the program funding will be spread over 6 fiscal years (FY 1983-FY 1988)? Provide an alternative request which accounts for this long project funding schedule.

Answer 5. The $7,000,000 requested in FY 1983 is to start Title I and II engineering and to procure the 16 new gas-filled circuit breakers. The installation of the 16 circuit breakers will be scheduled to minimize disturbances to normal plant operations. This will be accomplished by replacing the circuit breakers one at a time while the switchyard remains in service. All of the circuit breakers will be procurred under one contract to be let in FY 1983 in order to assure deliveries timed to coincide with the installation schedule and to obtain the units at minimum cost. It would not be cost effective to procure these circuit breakers on an option basis over a number of years. The estimated cost for the circuit breakers is $6,400,000. The remainder of the FY 1983 funding is for engineering. The spread of costs from FY 1983 to FY 1988 generally reflect the amount of work that will be completed in those years or ordered equipment received. This costing pattern is indicative of most construction projects.

Question 6. Provide a detailed description of work, cost breakdown of the estimated $12,940,000 in "special facilities" required at Oak Ridge, Tennessee for Project 83-N-402, and a milestone schedule.

Answer 6. The "special facilities" involved in this project are primarily the incinerator to be located at the Oak Ridge plant and the attendant facilities such as the off-gas treatment system, unload/cleaning system, data acquisition, etc. It is essential that the incinerator and auxiliary systems be procured and installed as one package to assure attainment of the environmental criteria.

The incineration facility at Oak Ridge will receive hazardous wastes, including PCB and nonfissile uranium contaminated waste. Material arriving at the incineration facility will be analyzed, blended and stored prior to high temperature incineration. All incinerator wastes will be disposed of through existing treatment or disposal facilities.

The plants at Paducah and Portsmouth will be provided facilities for decommissioning PCB transformers and for shipping the PCB contaminated fluids to the incineration facilities at Oak Ridge. Oak Ridge already has a PCB tansformer decomissioning facility.

## Cost Breakdown of $12,940,000 in "Special Facilities"

| | | |
|---|---|---|
| Incinerator | $4,500,000 | |
| Off-Gas Treatment | 350,000 | |
| ADP | 310,000 | |
| Unloading Cleaning Systems | 155,000 | |
| Miscellaneous Equipment | 175,000 | |
| | 5,490,000 | 5,490,000 |
| Fixed price procurement accounts for the remaining $7,450,000. This includes balance of plant items and installation such as: process piping system, water system (tanks and pumps), fire-water system, storm drains, motor control centers, instrumentation, process electrical lighting, environmental control (HVAC), instrument power, sodium hydroxide system (pumps, tanks, piping). | | 7,450,000 |
| | | $12,940,000 |

## Milestones

### Oak Ridge

| | |
|---|---|
| Design | 11-82 - 2/85 |
| Procurement | 9/83 - 9/85 |
| Construction | 7/84 - 7/87 |

### Paducah

| | |
|---|---|
| Design | 1/83 - 11/83 |
| Procurement | None |
| Construction | 9/83 - 11/84 |

### Portsmouth

| | |
|---|---|
| Design | 11/82 - 11/83 |
| Procurement | 6/84 - 1/85 |
| Construction | 6/84 - 6/85 |

Question 7. Provide a list of projects together with a detailed cost breakdown, justification, and priority listing for the FY 1983 request of $18,000,000 for General Plant Projects planned to be funded in Project 83-N-404.

Answer 7. The planned General Plant Projects, arranged in priority order by site, are as follows:

## Oak Ridge Gaseous Diffusion Plant

### Materials Characterization Laboratory $700,000

A dedicated materials testing laboratory is required to provide laboratory testing space for engineers and technicians in support of materials development and qualification for the current centrifuge designs as well as the Advanced Gas Centrifuge. The size of this facility is based on the projected requirements for development and qualification testing to support materials characterization tasks.

### Upgrade Air Conditioning, K-1004-D $900,000

The K-1004-D building technical services laboratories require a heating and air conditioning system which is dependable and which will provide close control of the temperature with lowered summertime humidity. Failure to replace the present system will result in continued excessive maintenance and operating costs and outages caused by unavailable spare parts.

### New Substation, K-25 Powerhouse Area $950,000

This project will provide a new substation to replace the outmoded and unsafe 2400 volt and 480 volt switchgear for which replacement parts are no longer available, and which is hazardous for personnel to operate and maintain.

### Material Test Facility $400,000

The facility will support FY 1984-FY 1990 activities of the Advanced Centrifuge Program and the Accelerated Life Test Program by providing full-length fabrication capability, including cleaning and inspection.

The only alternative to this project is to have the contractor fabricate tubes or negotiate contracts with the Centrifuge Manufacturers for the fabrication of full-length rotor tubes. This option would deprive the technical community of essential flexibility in scheduling and setting of priorities. It is probable that costs would be significantly greater, particularly if minor equipment changes are required.

### Rebuild Electroless Plating Facility $400,000

It is proposed to engineer and rebuild the Electroless Plating facility at K-1420. The project includes isolation of the facility from other K-1420 operations in order to reduce contaminants and improve reliability of product.

Failure to modernize, rebuild, and isolate the facility will result in continued problems in the areas of safety, corrosion control, product quality, and operating efficiency and could severely impact the availability of classified parts to all three gaseous diffusion plants.

| K-1501 Steam Plant Ash Removal Piping System Replacement | $600,000 |
|---|---|

Ash is removed from the coal fired boilers and the electrostatic precipators by means of a jet vacuum system that conveys the ash through an 8-inch piping system to a storage silo for eventual removal and burial. The existing piping system has deteriorated and developed leaks that not only create a dusting problem within the K-1501 Steam Plant but reduce the effectiveness of the vacuum jet ash removal. This project wil be the final phase of a program to upgrade the entire ash removal system as recommended in the Reliability Study Program.

If the piping system is not replaced and becomes unavailable due to a major leak, the operator is faced with unacceptable operating conditions.

A delay in the project will result in an increase in the maintenance effort to repair small leaks that develop and the potential for a prolonged outage due to a major leak will be greater.

| Remote Transformer Secondary Breaker Tripping - K-15 | $450,000 |
|---|---|

This project will provide necessary modifications to restore reliable protective relay systems which are now unreliable and have contributed to the failure of at least 10 transformers. Failure to provide this capability will result in continued unreliable operation and damage to other system equipment.

| New Power Supply To K-1008 Area | $400,000 |
|---|---|

This project will replace 14 pole-mounted transformers which supply power to the K-1008 area with a modern-type pod-mounted substation. The existing transformers have outlived their normal life span, and frequent power outages can be expected in this area unless they are replaced.

| Classified Burial Ground Expansion | $700,000 |
|---|---|

The Oak Ridge Gaseous Diffusion Plant classified burial ground will be expanded to include a 20-acre burial area with access roads. The existing classified burial ground is being utilized at a much faster rate than anticipated. Expansion of the burial area by 20 acres will ensure capability for continued disposal of classified waste at ORGDP.

| Air Conditioning Upgrade, Laboratory L | $500,000 |
|---|---|

This project would redesign and replace old and high maintenance systems with one system that will adequately control the temperature in the offices and laboratories. This project is required to provide adequate air conditioning and to avoid continued excessive maintenance costs.

Other Projects

| | |
|---|---|
| Propane Dispensing Facility | $ 100,000 |
| Machine Room Electrical Load Center Panels, K-1007 | 100,000 |
| Accelerated Gas Testing Laboratory | 200,000 |
| Replace Underground Fire-Water Mains from K-802 Fire Pumps to Street Mains | 150,000 |
| Polishing and Grinding Room, K-1401 Sheet Metal Shop | 250,000 |
| Improved Tails Withdrawal System | 225,000 |
| Upgrade Laboratory facilities, K-1004-C | 250,000 |
| Miscellaneous (Includes projects under $85,000 each) | 270,000 |
| Total ORGDP | $8,000,000 |

Paducah Gaseous Diffusion Plant

Cascade Building Low Bay Lighting Replacement, C-310/C-331/C-333 $450,000

The existing lighting system has been in service for approximately 28 years. This project will replace the existing inefficient and costly system with an upgraded energy efficient system of high-pressure sodium fixtures on the ground floors of the C-310, the C-331, and the C-333 Cascade Buildings.

Number 6 Sanitary Water Filter, C-611-H, Water Plant $400,000

Sanitary water demands in the next two years may require the addition of additional filter capacity at C-611. If the demand does not increase above a rate of 2.5 gpm per square foot of filter area, the project will not be required.

Circuit Breakers Upgrading, C-710, Laboratory Building $400,000

It has become increasingly difficult for maintenance to make necessary repairs and replacements to the circuit breaker system in C-710. This project will replace the breaker panels.

Storm and Sanitary Sewer Systems Upgrading Cascade Buildings $400,000

This project is the continuation of Utilities System Upgrading started in FY 1980 for the cascade buildings and will replace badly corroded, under capacity systems which often plug up. Failure to replace these systems will cause increased maintenance and continued unacceptable performance.

Upgrade Freight Elevators (4), Cascade Buildings $675,000

The freight elevators in the 4 Cascade Process Buildings (C-331/C-333/C-335/C-337) do not reflect current design criteria with regard for safety standards, and are rapidly approaching the point where their reliability will be seriously compromised. The cumulative effect of usage, age, and equipment modification is currently being evidenced by the increasing difficulty being experienced in keeping the units in operating condition.

### Cascade Building Low Bay Lighting Replacement, C-335/C-337 $450,000

The existing lighting system has been in service for approximately 27 years. This project will replace the existing inefficient and high maintenance system with an upgraded energy efficient system of high-pressure sodium fixtures. Failure to replace this old system will result in increased maintenance and continued excessive energy costs.

### Other Projects

| | |
|---|---|
| Sanitary Water System Upgrading, Cascade | $ 275,000 |
| Cooling Tower Electrical Upgrading, C-631 | 250,000 |
| Switchyard Lighting Upgrading | 230,000 |
| Load Forecaster, C-300, Central Control Facility | 270,000 |
| Mechanical Reliability Testing Laboratory Uprating, C-710 | 100,000 |
| Miscellaneous (Includes projects under $85,000 each) | 300,000 |
| Total Paducah Gaseous Diffusion Plant | $4,200,000 |

## Portsmouth Gaseous Diffusion Plant

### X-633-2B and X-630-2B Cooling Tower Conduit $935,000

Electrical power is supplied to the various cooling towers for fan motor operations, sprinkler system heaters; tower lighting; and control, alarm, and communication systems. Over the past 25 years, maintenance of this conduit has involved piecemeal replacement of individual sections on an as-needed basis. The most recent attempts at such piecemeal replacement have demonstrated that the entire conduit and cabling system is not capable of being maintained and is in need of replacement. This project wil provide for the replacement of the existing conduit, fittings, support brackets and associated cable on the X-633-2B and X-630-2B cooling towers with new material. Failure to replace these items will result in excessive maintenance costs, risk of personnel injury, and risk of tower damage with resultant loss in production.

### Ambient Air Monitoring System $490,000

Present air monitoring stations located north, south, east, west, and southwest of the diffusion plant will be upgraded in this project to give them "state of the art" capabilities for radiation detection. In addition, a significant number of new stations will be added to the monitoring network to provide a larger, more comprehensive data collection and emergency monitoring system.

### Bus Differential Relays $440,000

This project will provide for the installation of two sets of three bus differential relays in the X-533 Switchyard. These overaged relays are no longer capable of providing reliable service. Failure to replace these relays increases load security risks.

Waste Sampling Station, X-744G $630,000

The presence of many radioactive contaminants in plant waste materials requires that a suitable sampling facility be built to correctly sample these materials without spreading contamination throughout the facility and exposing operating personnel. A glove box design similar to that used in the X-345 High Assay Storage Facility is needed to meet protective requirements.

Railroad Car Unloading Facility $350,000

This facility would provide the most convenient and reliable form of transportation to satisfy the needs of the plant for procuring bulk materials in the most economical quantities. Failure to provide this facility will continue to put us at a disadvantage, as in the past, because of uncertainties caused by vendors' and truckers' strikes and severe weather.

Paving of Patrol Road $400,000

The present patrol road condition erodes the security guard's ability to adequately perform his duty in accordance with improved security activities now required for Strategic Nuclear Materials (SNM). It is estimated that approximately 16,000 feet of existing unimproved roadway will be upgraded.

Renovation of X-744G Warehouse $740,000

The warehouse will be selectively upgraded to enhance its material condition, utility systems and weather tightness. It is in a highly deteriorated condition. Failure to upgrade the warehouse will result in continued excess maintenance and possible spoilage of its contents.

Area Control Room (ACR) $438,000

The area control room air conditioners have been in continuous service since 1955. The heat load due to process operation and the large amount of electrical equipment and instrumentation in these areas results in year-round air conditioning operation. The air conditioning units will be replaced to maintain the proper temperature and humidity conditions. Failure to replace the units will result in continued excessive maintenance and possible outages because of unavailability of spare parts.

Decontaminate Laundry Effluent $492,000

The results of recent radiological analyses indicated that approximately six kilograms of uranium are released to the environment annually. Most of this uranium enters the sanitary sewer system at the laundry.

This project will provide for the treatment of laundry effluent by procuring and installing a skid-mounted assembly, complete with necessary tanks, pumps, control panels, and osmosis membrane tubes.

The new treatment equipment will be housed in a new 20' x 30' x 12' Butler type building with the necessary utilities. This installation is required in order for the plant to operate as required by the NPDES permit.

## Other Projects

| | |
|---|---|
| $SO_2$ Bulk Storage Facility | $ 130,000 |
| Enclosed X-700 Sandblast Facility | 200,000 |
| Miscellaneous (Includes projects under $85,000 each) | 255,000 |
| Total Portsmouth Gaseous Diffusion Plant | $5,500,000 |

All Other, Oak Ridge Operations $300,000

Miscellaneous other projects are mainly for improvements to the the Security Division, Patrol Range, motor pool and security operations center.

Total FY 1983 General Plant Projects $18,000,000

| | |
|---|---|
| Question 8. | Why is $8,000,000 requested for Project 83-N-405 in FY 1983, since the program funding will be spread over a period of five fiscal years (FY 1983-FY1987)? Provide an alternative request which accounts for this long project funding schedule. Provide a description of the utilities and related costs to be installed for $12,200,000. |
| Answer 8. | In order to initiate engineering work, purchase long-lead procurement items, and relocate equipment in preparation for the construction activity, $8,000,000 in obligational authority is needed in FY 1983. The spread of costs from FY 1983 to FY 1987 generally reflect the amount of work that will be completed in those years or ordered equipment received. This costing pattern is indicative of most construction projects. The $8,000,000 requested for FY 1983 is for the following. |

| | | |
|---|---|---|
| Title I and II Engineering | | $3,400,000 |
| Long Lead Procurements | | 2,200,000 |
| Oak Ridge - Switchgear | 500,000 | |
| Paducah - Switchgear | 600,000 | |
| Portsmouth - Dry Air Compressors | 300,000 | |
| - Circuit Breakers | 800,000 | |
| Construction - Relocation and Upgrading of Raw Water Pumping Switchgear at Paducah | | 1,100,000 |
| Contingency | | 1,300,000 |
| Total | | $8,000,000 |

The following items comprise the $12,200,000 estimated for utilities in the project

| | | |
|---|---|---|
| Oak Ridge | | $3,500,000 |
| K-1004A Substation | 1,000,000 | |
| K-1131 Substation | 1,200,000 | |
| K-1420 Substation | 1,300,000 | |
| Paducah | | $6,100,000 |
| C-310 Circuit Breakers Replacement | 6,000,000 | |
| C-331 Circuit Breakers Replacement | 2,200,000 | |
| C-333 Switchgear Replacement | 3,300,000 | |
| Portsmouth | | $2,600,000 |
| X-501, X-501A Switchgear and Distribution Center | 1,000,000 | |
| X-705 Transformer and Motor Control Center | 1,000,000 | |
| X-300 Substation | 300,000 | |
| X-342 Auxiliary Substation | 300,000 | |
| Total | | $12,200,000 |

The items included in the project have been identified in the on-going reliability assessment program as requiring corrective action. Any reduction in requested funding levels will increase costs due to escalation and increase the risk of serious operational interruptions to the gaseous diffusion cascade.

Question 9. Provide detailed justifications and milestones for Project 82-R-413, as well as a rationale for the FY 1983 budget request of $20,900,000. Also provide an alternative funding request which accounts for the long project funding schedule.

Answer 9. The justification for this project is twofold: (1) it will provide a safer more efficient operation utilizing new autoclaves and double-hook cranes, and (2) it will reduce the potential for major and minor $UF_6$ releases with associated hazards to personnel, limit the release of toxic material to the environment, and reduce the loss of valuable $UF_6$ material. Originally, $UF_6$ feed and transfer operations at the gaseous diffusion plants were accomplished through the use of open-type, metal-sided steam chests which provided no containment capability and offered little operational flexibility. Several years ago, many of these open vessels had deteriorated beyond economical repair and were replaced with low pressure autoclaves. Within recent years, high pressure autoclaves, designed to provide improved containment, have been utilized as replacement for both of the above vessel types. The inherent improved safety features of these autoclaves have enhanced personnel protection and simplified the operational procedures. This project completes replacement of all remaining non-containment vessels with improved containment-type autoclaves. Additionally, certain other safety systems are being incorporated to minimize the potential release of $UF_6$ to the atmosphere in relatively high risk areas where liquid $UF_6$ is handled.

A review of liquid $UF_6$ cylinder handling by existing cranes, considering the lift height, proximity of personnel and enclosed areas of movement, has resulted in a recommendation that double-hook cranes be installed in certain areas to improve the operational reliability and safety of cylinder handling.

A delay in this project would result in a corresponding delay in providing these improved safety and $UF_6$ containment measures and would prolong the potential exposure of plant populations and the public to a higher risk of accidential release of hazardous materials.

The $20,900,000 is required to maintain the project on the current schedule. The funds will be used primarily to install the equipment procured with FY 1982 funds and for facility and equipment modifications. Specifically, the funds will be used to:

1. Contract for modifying existing buildings to accept the new autoclaves and handling equipment including enclosing the vaporization facilities at Paducah.

2. Contract for installing new autoclaves and handling equipment with attendent supporting systems and equipment.

3. Contract for uprating low pressure autoclaves to provide improved containment capabilities.

The installation schedule is geared to the equipment delivery schedules. The funding schedule provides for the replacement of steam chests and modification of low pressure autoclaves at the earliest possible date. Any reductions in the proposed funding schedule will result in higher costs through escalation resulting from an extension of the project completion date and from special measures which would be required to preserve and store the autoclaves and other equipment whose installation would be delayed.

## MILESTONES

### OAK RIDGE

Feed and Withdrawal Facility

| | |
|---|---|
| Design | 10/81 - 4/83 |
| Procurement | 7/82 - 12/84 |
| Construction | 4/83 - 9/85 |

Toll Enrichment Facility

| | |
|---|---|
| Design | 10/81 - 4/83 |
| Procurement | 7/82 - 7/84 |
| Construction | 4/83 - 9/85 |

### PADUCAH

Feed Facilities

| | |
|---|---|
| Design | 10/81 - 6/83 |
| Procurement | 5/82 - 4/86 |
| Construction | 1/83 - 9/86 |

Withdrawal Facilities

| | |
|---|---|
| Design | 10/81 - 12/82 |
| Procurement | 1/83 - 3/84 |
| Construction | 1/83 - 9/86 |

Toll Enrichment Facility

| | |
|---|---|
| Design | 10/81 - 12/82 |
| Procurement | 1/83 - 3/84 |
| Construction | 1/83 - 9/86 |

### PORTSMOUTH

Feed & Withdrawal Facility

| | |
|---|---|
| Design | 10/81 - 2/83 |
| Procurement | 10/82 - 3/84 |
| Construction | 3/83 - 3/85 |

High Assay Sampling Area (HASA)

| | |
|---|---|
| Design | 10/81 - 7/84 |
| Procurement | 1/84 - 6/86 |

Question 10. Provide detailed justifications and milestones for Project 82-R-416 and Project 81-R-506, environmental protection and safety improvements at gaseous diffusion plants.

Answer 10. A list of the subprojects, justifications, and milestones for each is as follows:

## PROJECT 81-R-506, ENVIRONMENTAL PROTECTION AND SAFETY, IMPROVEMENTS, PHASE I, GASEOUS DIFFUSION PLANTS

### A. OAK RIDGE GASEOUS DIFFUSION PLANT

New National Pollutant Discharge Elimination System (NPDES) permits are being negotiated, for the Oak Ridge facilities, with U.S. Environmental Protection Agency (EPA) Region IV in Atlanta. While the actual content of the new permits cannot be known at this time, EPA is trying to move the monitoring points from the present locations to the discharge of each process. EPA also wants to put DOE on a compliance schedule for all pollution sources in order to achieve Best Available Treatment Economically Achievable (BAT) at each source.

1. Coal Pile Runoff: (Compliance with NPDES Permits and BAT)

   This project provides the collection and transfer facilities necessary to send the coal pile runoff over to the Central Neutralization Facility. DOE recently received a Notice of Violation for noncompliance in this area from U.S. EPA Region IV.

2. Chromium Sludge Collection: (Operational Considerations and The Clean Water Act)

   A chromium sludge collection system will be installed to contain the chromium sludges from the Recirculating Cooling Water (RCW) System. The present pond is filling up with sludge and new capacity is needed. Use of the present pond as a chromium sludge collection pond is technically illegal under the Clean Water Act.

3. Liquid Effluent Treatment Facility K-1419:

   a. K-1407-E Central Neutralization Facility (CNF): (The Clean Water Act (CWA))

      This project provides the facilities for the neutralization, precipitation, and solids settling for the coal pile runoff, ion exchange column regeneration wastes, metal plating wastes, and other aqueous streams requiring similar treatment. The discharge without treatment of the acidic and alkaline streams is a violation of the Clean Water Act and can cause violations of the NPDES permit for the ORGDP.

   b. K-1407-E Central Sludge Treatment Facility: (The Clean Water Act (CWA); the Resource Conservation and Recovery Act (RCRA))

      This project is needed to treat the sludge generated by the CNF and other low volume sludge generating areas. Some of these sludges could be considered hazardous under RCRA if they fail the EPA toxicity test. This facility would also help to meet DOE's guidelines for radiation exposure by removing and fixing the contaminated sludge from the K-1407-C lagoon so that it can be closed out.

c. K-1420 Floor Pan and Cylinder Cleaning Effluent Treatment

Project will provide facilities for treatment of K-1420 floor pan and cylinder cleaning effluents. DOE guidelines are for radiation releases to be As Low As Reasonably Achievable (ALARA). Also, EPA regulations 40 CFR 190 limiting public exposure from the nuclear fuel cycle to 25 mrem per year.

## B. PADUCAH GASEOUS DIFFUSION PLANT

New NPDES permits are being negotiated for the Paducah facilities, with U.S. EPA Region IV in Atlanta. While the actual content of the new permits cannot be known at this time, EPA is trying to move the monitoring points from the present locations to the discharge of each process. EPA also wants to put DOE on a compliance schedule for all pollution sources in order to achieve Best Available Treatment Economically Achievable (BAT) at each source..

1. C-400 Source Treatment Facility: (The Clean Water Act and the Resource Conservation and Recovery Act (RCRA), also DOE (ALARA))

   The project provides a treatment facility to provide source treatment for hazardous chemical discharges. Certain of the waste streams are subject to the BAT requirements of the Clean Water Act and the Resource Conservation and Recovery Act.

2. Effluent Treatment System: (Resource Conservation and Recovery Act)

   Project will provide collection and treatment of low pollutant level effluent from several plant sources. Landfarming of chlorinated solvents is no longer acceptable.

3. Oil and Chemical Storage and Containment: (The Clean Water Act (CWA))

   Project will provide a new oil and chemical storage shelter. Section 311 of the CWA says that there should be no discharge (which includes spills and leaks) of oil or hazardous substances onto or into the Waters of the United States. The recently enacted Comprehensive Environmental Response, Compensation, and Liability Act of 1980 also deals with reporting and cleaning up spills of hazardous materials.

4. Hazardous and Toxic Chemical Sludge Fixation Facility: (RCRA)

   This project is necessary to change sludges from facilities such as the C-400 Source Treatment Facility into a non-hazardous form so that disposal will not be regulated by RCRA.

## C. PORTSMOUTH GASEOUS DIFFUSION PLANT

1. Biological Denitrification: (NPDES Permit No. OH0006092)

   Project provides for construction of a new treatment facility to reduce nitrates and remove heavy metals in the waste streams from the Decontamination Building.

   Schedule of Compliance, Part I-B, p. 20, Outfall 003B.

2. Hazardous Waste Materials Disposal Area: (Resource Conservation and Recovery Act (RCRA))

   Provides disposal areas for sludges, from Biological Denitrification, Coal Pile Runoff Treatment, X-701B Treatment, X-344A Cell Cleaning Waste, as well as from other low volume sludge generating areas, which meet the intent of RCRA and State of Ohio regulations.

## PROJECT 82-R-416 ENVIRONMENTAL PROTECTION AND SAFETY MODIFICATIONS, PHASE II, PORTSMOUTH, OHIO, GASEOUS DIFFUSION PLANT

1. X-710 Laboratory Treatment: (NPDES Permit No. OH0006992)

   The project provides a new batch treatment facility for pH adjustment, metals precipitation and organic material filtering.

   Schedule of Compliance, Part I-B, p. 21, Outfall 003A.

2. X-344A Electrolytic Cell Cleaning Waste Treatment:

   The project provides a treatment process for pH adjustment and precipitation of metallic fluorides.

   To prevent fluoride violations at NPDES Permit OH0006094, Outfall 009A.

3. Interim Storage for Hazardous Material:

   The project provides facilities for the storage of hazardous materials which meet the regulations of the Resource Conservation and Recovery Act.

### MILESTONES

81-R-506

| | OAK RIDGE |
|---|---|
| Design | 1/83 - 4/84 |
| Procurement | 5/83 - 3/85 |
| Construction | 11/84 - 8/87 |
| | PADUCAH |
| Design | 10/82 - 10/83 |
| Procurement | 10/83 - 5/85 |
| Construction | 6/83 - 4/87 |
| | PORTSMOUTH |
| Design | 1/83 - 8/84 |
| Procurement | 7/84 - 5/86 |
| Construction | 12/84 - 11/86 |

81-R-416

| | |
|---|---|
| Design | 12/82 - 6/84 |

Question 11. Provide the Subcommittee with a copy of the December 1981 uranium enrichment operating plan.

Answer 11. A copy of the December 1981 uranium enrichment operating plan is included as requested.

# OFFICE OF URANIUM ENRICHMENT AND ASSESSMENT URANIUM ENRICHMENT OPERATING PLAN, DECEMBER 1981

## Uranium Enrichment Operating Plan

### I. Introduction

For near term and long range enrichment program planning and budget requirements, a number of alternative operating plans are examined annually to ensure efficient and economical operation of the enrichment enterprise to meet demand. The primary objectives of this analysis are: (1)to update the DOE enrichment operating plan for the period FY 1982-FY 1995 and; (2) to reexamine the validity of the overall enrichment strategy based on exhaustive analyses conducted during the summer of 1980. Four major issues are addressed in this update; (1) the appropriate pace of the Gas Centrifuge Enrichment Plant (GCEP) including the potential impact of the availability of AIS technology; (2) the proper minimum level of low enriched inventory which should be maintained to support enrichment operations; (3) the appropriate near and long-term gaseous diffusion plant (GDP) power levels; and (4) the extent to which the transaction tails assay should be relied upon to meet demand.

This update is aimed at achieving the DOE Uranium Enrichment program goals and objectives of:

—reestablishing the United States as a dependable world supplier of enrichment services

—providing of enrichment services at the lowest cost, in existing and planned facilities

—operation of the enrichment complex in a safe, environmentally acceptable and businesslike manner.

### II. Methodology

The analysis evaluates the economics and characteristics of a series of alternative operating plans developed for various scenarios of separative work demand, power cost growth, natural uranimum costs, GCEP construction schedules, and Advanced Isotope Separation (AIS) plant availability. This analysis makes use of two computer models; a uranium enrichment production planning model and a financial analysis model.

Inputs into the production planning model include gaseous diffusion plant (GDP) and GCEP production schedules; domestic, foreign, and Government demands for enriched uranium; beginning inventories of natural and enriched uranium; and operating and transaction tails assays. Included in the output of the production planning model are annual separative work requirements and annual inventories of enriched and natural uranium.

The financial analysis model is used to determine annual prices, revenues, and costs from each plan based on the methodology used in pricing uranium enrichment services. This methodology is consistent with published criteria and the legislative requirements of section 161v of the Atomic Energy Act of 1954, as amended. The output of this model is used to determine the discounted and undiscounted long-range economics of each alternative operating plan.

## III. Assumptions

### III.A. Enrichment Services Requirements

### III.A.1 Civilian

The nuclear power industry demand for enrichment services is based on the August 1981 Office of Uranium Enrichment and Assessment (OUEA) forecast of nuclear power growth to be serviced by DOE which is shown in the following table. The mid-range estimate is used in the base operating plans with the low-estimate used for determining the sensitivity of long-range economics to demand.

Installed Nuclear Electric Generating Capacity

(Net Gigawatts Electric)

| | U.S. | | | Non U.S. | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low | Mid | High | Low | Mid | High | Low | Mid | High |
| 1980 | 50 | 50 | 50 | 34 | 34 | 34 | 84 | 84 | 84 |
| 1985 | 80 | 90 | 99 | 44 | 47 | 52 | 124 | 137 | 151 |
| 1990 | 117 | 122 | 126 | 55 | 60 | 70 | 172 | 182 | 196 |
| 1995 | 130 | 140 | 150 | 67 | 86 | 104 | 197 | 226 | 254 |
| 2000 | 148 | 170 | 195 | 83 | 96 | 120 | 231 | 266 | 315 |

The demand for separative work in the near-term reflects specific contractual data. For the longer term, separative work demand reflects standardized boiling-water and pressurized-water once-through-cycle reactor models using historical lead time information.

### III.A.2 Government Requirements

Enrichment demand must also include Government needs; that is, the Naval Reactors' program, nuclear research and development programs, the defense related production reactor program and the weapons program. Naval Reactor and R&D needs are relatively stable and reflect estimates provided by the program offices to the Oak Ridge Operations Office earlier this year. Production reactor and weapons need estimates are less uncertain. The requirements used in the analysis are based on the range of estimates provided in a classified (SRD) memorandum to the Assistant Secretary for Nuclear Energy from the Assistant Secretary for Defense Programs on August 25, 1981. A subsequent memorandum dated September 24, 1981, from the Defense Program Acting Deputy Assistant Secretary for Nuclear Materials modified slightly the enriched uranium requirements for the production reactor program.

### III.A.3. DOE Inventory Requirements

In September 1978, the Assistant Secretary for Resource Applications approved the policy of maintaining a minimum low-enriched stockpile level of 14 million SWU. The minimum low-enriched stockpile level as approved was comprised of:

- A 9-million-SWU working inventory to serve as a buffer between the levelized production of enriched uranium and the intermittent day-to-day shipments of finished enriched uranium product. This is equivalent to about 90 days' production from the fully powered GDP's plus GCEP. A recent analysis by the Oak Ridge Operations Office shows the 90 day requirement still to be reasonable (Attachment 1).

- In addition, a 5-million-SWU inventory "set aside" for possible use as part of U.S. efforts to improve international nuclear fuel assurances as described in President Carter's response to Section 104(b) of the Nuclear Nonproliferation Act (NNPA) of 1978 was established. Based on events which have occurred since that time, it is no longer evident that such an inventory would have any influence on the actions of other nation's with regard to adherence to U.S. nonproliferation standards. Consequently, the sensitivity of the 5-million-SWU "set aside" on enrichment plant operations and costs is also investigated.

## III.B. Separative Work Production

### III.B.1 Existing Gaseous Diffusion Plants (GDP's)

DOE has power contracts with the Tennessee Valley Authority (TVA) for Oak Ridge and Paducah; Electric Energy, Inc. (EEI) for Paducah; and the Ohio Valley Electric Corporation (OVEC) for Portsmouth. The annual three-site firm-contract power levels and corresponding separative work production at each of the GDP's for the period FY 1982 through FY 1990 are shown below. In deriving the separative work production, it has been assumed (based upon historical data) that actual electric power deliveries to the plants after FY 1983 will be 96 percent of the contract levels due to unscheduled outages.

GDP Power and Separative Work Production

| FY | Power - MW[a] | | Production[b] (Millions of SWU) |
|---|---|---|---|
| | Contract | Budget | |
| 1982 | 4026 | 2660 | 9.8 |
| 1983 | 4548 | 2660 | 9.8 |
| 1984 | 5780 | | 20.9 |
| 1985 | 6480 | | 23.0 |
| 1986 | 6480 | | 23.0 |
| 1987 | 6560 | | 23.3 |
| 1988 | 6635 | | 23.8 |
| 1989 | 6915 | | 24.7 |
| 1990 | 7160 | | 25.4 |

a/ Includes 75 MW for ORNL & Y-12.

b/ Based on budget power in fiscal years 1982 and 1983.

In the near-term, any reductions in power usages below the firm contract level could result in DOE paying capacity charges for power not taken (equivalent to about 25-30 percent of what would have been the charge for the power). Under present arrangements, DOE can cancel contracted power deliveries with no penalty by providing an eight year notice period to TVA, a ten year notice period to EEI and a five year notice period to OVEC. In the period 1990-1995, the current contracts with the three power suppliers will expire and negotiations must begin in the very near future (particularly in regard to TVA) to contract for power requirements in the 1990's.

In developing the alternative operating plans, near term power usage was reduced to the extent possible without shutting down the plants in order to take advantage of the economics of these cuts. For the longer term, replacement of GDP capacity was assumed when appropriate.

### III.B.2 Gas Centrifuge Enrichment Plant (GCEP)

The availability of Set IV GCEP technology was assumed in developing the alternative operating plans. Set IV technology is an extrapolation of the technology already developed. A performance increase of 50 percent will be achieved through a modest increase in speed and improved flow management. Development of this design is currently underway and about one-half of the performance increase has already been achieved in an early test centrifuge. The Set IV improvement ojectives are reasonable, the probability of this technical achievement is high, and it is expected with high confidence that the 50 percent increased performance design will be available for installation in the third GCEP process building; and can be retrofitted into Process Buildings 1 and 2.

The current schedule for GCEP calls for the completion of the first two buildings by 1989 with buildings 3 through 8 brought on-line in the period 1990 to 1994. The analysis also evaluated the impact of alternative construction schedules including: an accelerated schedule (compression of the schedule so that the entire eight buildings would be completed by 1992); a one-year delay in completion of buildings 3 through 8; a two-year delay in completion of buildings 3 through 8; and, a four year stretch case (i.e., a proportionate delay in each successive building with essentially no delay in building 1 stretching to a four year delay in building 8). A 2-building GCEP case was also evaluated as well as an indefinite deferral case (i.e., delay past 1995) which is characterized as a no GCEP case. Attachment 2 summarizes the assumed cost and production schedules for each GCEP alternative studied.

### III.B.3 Advanced Isotope Separation (AIS) Technologies

At present, one plasma separation method and two laser methods of uranium isotope separation are under intensive development by DOE. These methods show potential for being very low-cost methods of uranium isotope separation. The AIS processes are still in the technology development stage. As a result of the development program, confidence continues to grow that the AIS technology that is selected will succeed in meeting with cost goals. While these cost projections have remained relatively constant based upon several indepth conceptual plant designs, reasonably definitive values for capital and operating costs must await the operation of the Development Module (DM). Current plans assume that the DM will be a FY 1984 line item with initial operation in 1988. At least one year of operational experience with the near production sized equipment in this facility is necessary to firmly establish the operating parameters and permit an estimate of reliability and maintainability. Thus, the information required for DOE to commit to an AIS plant would not be available before 1989. In this analysis, the sensitivity of AIS availability in the mid-1990's using current cost estimates on operating plan economics is investigated. Attachment 3 summarizes the assumed AIS costs.

### III.C. Tails Assay

The operating tails assay determines the relative amounts of feed and separative work used to produce a given amount of enriched uranium. The transaction tails assay determines the amount of feed the toll enricher customer must deliver for a given product requirement. Taken together, the specification of these assays is a primary means of both regulating production and managing DOE feed stockpiles.

In this analysis, the operating tails assay is permitted to be increased above the current level of 0.20 percent U-235 as necessary to assure that customer needs are met and the minimum low-enriched uranium stockpile level maintained. Several different transaction tails assay schedules are used in the analysis ranging from maintaining the current 0.20 percent U-235 level through 1995 to increasing the transaction tails assay to 0.25 percent U-235 beginning in FY 1984 (i.e., the earliest date considering the 540 day notice period required under the contract). It might be noted that at customer request, the adjustable Fixed Commitment Contract has a provision which permits the customer to terminate the contract free of charge in the event of an increase in transaction tails assay above a level of 0.25 percent U-235.

### III.D. Other Major Economic Assumptions

#### III.D.1 Power Costs

1983 electricity costs were assumed to be 36.0, 28.4, and 27.0 mills/kWh for TVA, EEI and OVEC, respectively, reflecting the latest estimates from the power suppliers. Differential escalation of energy relative to constant labor and construction costs was assumed at alternative rates of 1.5 and 3.0 percent/year. These rates appeared to be in line with the projections made by other major groups. For example, in the 1980 EIA Annual Report to Congress (published in March 1981), a 2.3 to 2.6 percent real increase in the industrial power rates was forecast in the period 1978-1995.

#### III.D.2. Feed Costs

Annual prices ranging from $116.80/kgU to $132.40/kgU were used in the period 1983 to 1990 and $132.40/kgU thereafter based on latest estimates (Attachment 4). These represent average prices to domestic buyers reflecting contracts with prices already agreed upon on at market prices derived from the 1981 Survey of United States Uranium Marketing Activity (DOE/NE-0013).

For sensitivity analysis, an alternative lower feed price of $96/kgU per annum was also assumed.

## IV. Economic Analysis of Alternative Operating Scenarios

### IV.A. Economic Criteria

Enrichment planning cannot be based on maximizing profit as might be the case in the private sector because of the cost recovery pricing requirement and the limitations as to the type of activities to be conducted. The economic criteria upon which DOE enrichment planning is based is minimizing costs, both to the Government and to the customer. The specific economic criteria established to evaluate the 20 year operating scenarios are:

- o Average SWU Price
- o Total Enterprise Cost
- o Total Customer Cost
- o GDP Cumulative Power Usage

The average 10 year SWU price provides one appropriate measure of minimizing production cost. The cost of separative work is particularly important as price again becomes a major factor in customer determinations on whether to remain with the U.S. or go to non-U.S. sources of supply. The Total Enterprise Cost (TEC) represents the combined controllable costs of DOE and its customers (i.e., the total out-of-pocket costs of separative work and feed for producing enriched uranium). The TEC is calculated on both a discounted and undiscounted basis. For analysis purposes, a 10 percent discount rate and a constant dollar basis were used as prescribed in OMB circular A-94. The customer cost of enriched uranium provides still another criteria for economic evaluation. Customer cost reflects DOE SWU pricing policy as well as feed costs. This criteria is also evaluated on both a discounted and an undiscounted basis. Finally, another parameter of interest is the energy efficiency of a given plan which can be related to the amount of energy consumed by the gaseous diffusion plants.

These criteria are weighed in conjunction with several additional factors to reach an overall balanced judgement with respect to the recommended operating plan. These factors include:

- o flexibility of options to respond to future changes in demand such that DOE's capability to meet its contractual commitments is assured.
- o impact on DOE's competitive position and credibility in the international market.
- o technical viability and achievability of the strategy.
- o impact on near-term enrichment budgets.

### IV.B. Analysis Results

Tables 1 through 11 summarize the results of economic analyses that were performed for a number of alternative operating conditions. The analysis focused on the following four major issues:

- The appropriate pace of GCEP (including the impact of the availability of AIS).
- The appropriate level of the enriched uranium stockpile.
- The appropriate GDP power levels both in the near and long term.
- The effect of raising the transaction tails assay early (i.e., 1984).

### IV.B.1 GCEP Timing

An issue, raised periodically in light of continued decreases in the demand for enriched uranium, is the need for and the timing of GCEP. For analysis purposes, a base case operating plan was developed to meet the mid-civilian-low-government demand assuming a 9 million SWU minimum inventory requirement. The base case further assumed the full 8 building GCEP on the currently planned schedule with set IV gas centrifuge technology available beginning with process building 3 and retrofitted in buildings 1 and 2 as machines fail. A series of alternative operating plans to meet the same demand were then developed for various GCEP availability cases using different mixes of gaseous diffusion plant production, tails assays, etc. The various GCEP cases analyzed ranged from a case where the GCEP construction schedule is accelerated by about two years, various delay scenarios, a 2-building GCEP variant with subsequent capacity deferred beyond 1995, and a no GCEP case (i.e., all new capacity deferred beyond 1995).

Table 1 compares each of the alternative plans on a FY 1983 dollar basis assuming differential power cost escalation of 3 percent p.a. using the evaluation criteria set forth in section IV.A. The data in the first five columns clearly indicate that it is desirable in all respects to build GCEP as rapidly as possible. Accelerating the GCEP schedule (column 1 versus column 2) from the current schedule reduces the average DOE price of separative work over the next 20 year period by about $1.60. The total out-of-pocket costs of producing enriched uranium (i.e., Total Enterprise Costs (TEC)) are reduced by $1,207 million ($388 million discounted). Customer costs of enriched uranium are correspondingly reduced by $822 million ($334 million discounted). Accelerating the GCEP schedule also results in electrical energy savings of almost 4,000 megawatt years.

Conversely, delaying GCEP results in adverse economic consequences. Comparing column 3 to column 2, for example, shows a one-year delay in GCEP to result in a higher average DOE SWU price for separative work of $1.54/SWU over the next 10 years and $2.09/SWU over the following 10-year period. The TEC is increased by $953 million ($416 million discounted) and customer costs are increased by $969 million ($367 million discounted). Additional electrical energy consumption amounting to 3,175 megawatt-years also occurs.

A comparison of columns 2 and 7 shows the advantages of proceeding with GCEP at this time. There is a substantial price reduction over the long-term, amounting to about $20/SWU in the 1990's. In the near term, however, there is a small price disadvantage reflecting interest charges in GCEP capital costs. The TEC and customer cost savings are very substantial amounting to $11,898 million ($1,469 million discounted) and $5,524 million ($1,035 million) respectively. Electrical energy savings are also considerable amounting to 29,211 megawatt-years (this is equivalent to the total power generation of 2 large size electrical generating stations over the 20-year period).

Finally, a comparison of column 6 with column 7 shows little or no economic advantage of a 2 building GCEP. The average DOE SWU price $4.98/SWU higher over the next ten years and $.99/SWU higher in the 1993-2002 period. The TEC is lower on an undiscounted basis ($2,516 million) but higher on a discounted basis ($424 million). Customer costs are higher by $1,617 million ($906 million discounted). The 2 building GCEP does permit some savings in electrical energy usage amounting to 4,292 megawatt-years when compared with the no GCEP case.

Sensitivity analyses were also conducted to determine the impact that a change in the various parameters would have on the conclusions reached. These are discussed below.

## Lower Power Cost Escalation Sensitivity

Selected cases from the previous analysis were rerun to determine the effect a downward change in differential power cost escalation (i.e., to a 1.5% p.a. rate) might have on the conclusions reached from Table 1. The results are not significantly different as shown in Table 2. Even at the lower power cost escalation rate, it is economically advantageous to build GCEP as rapidly as possible. A comparison of columns 1 and 2 shows that delaying the GCEP schedule by one year would increase the TEC by $801 million ($354 million discounted) and increase customer costs by $831 million ($314 million discounted). The average DOE SWU price increases by $1.35/SWU over the next 10-year period and by $1.79/SWU in the 1993-2002 period.

A comparison of columns 1 and 4 also shows a continuing large advantage of proceeding with the full GCEP on the current schedule even at the lower differential power cost escalation rate. There remains a substantial price reduction over the long term of $13.19/SWU although there is a near term price disadvantage reflecting interest charges on GCEP capital costs. TEC and customer costs are significantly lower by $9,648 million ($873 million discounted) and $3,412 million ($463 million discounted) respectively.

Comparing columns 3 and 4 shows that there is even a greater economic disadvantage to a 2 building GCEP versus no GCEP. The average DOE SWU price is $5.25/SWU higher over the next 10-year period and $1.99/SWU higher in the 1993-2002 period. The TEC is lower on an undiscounted basis ($2,277 million) but higher on a discounted basis ($485 million). Customer costs are higher by $1,832 million ($962 million discounted).

## Demand Sensitivity

Tables 3 and 4 compare the economics and energy efficiency of alternative operating plans using various GCEP schedules assuming the mid-civilian requirements in concert with a high-government demand scenario. The data on Table 3 reflect an assumed 3 percent p.a. differential power cost escalation rate whereas the data on Table 4 assume 1.5 percent p.a. differential power cost escalation. The use of a high versus low government demand turns out not to be a significant parameter for evaluating GCEP as the economic and energy efficiency benefits of GCEP derived from these tables are very similar to the benefits derived from Tables 1 and 2 which are based on a low-government demand scenario.

Table 5 compares the economics and energy efficiency of alternative operating plans incorporating GCEP on the currently planned schedule versus cancelling the project assuming low-civilian and low-government requirements. Columns 1 and 2 assume a 3 percent differential power cost escalation rate whereas columns 3 and 4 assume a differential power cost rate of 1.5 percent p.a. Even for the lower demand, the long-term economic and energy efficiency benefits favor continuation of GCEP. At a 3 percent p.a. differential power cost escalation rate, GCEP results in a $13,479 million ($1,211 million discounted) reduction in TEC and a $5,591 million ($912 million discounted) reduction in customer cost. At a 1.5 percent p.a. differential power cost escalation rate, GCEP results in a $10,179 million ($366 million discounted) reduction in TEC and a $2,457 million ($94 million discounted) reduction in customer cost. The energy efficiency benefits of GCEP are substantial resulting in electrical energy savings of over 40,000 megawatt years. The average DOE SWU price over the next ten years is higher with GCEP by $4.80/SWU because of interest charges on GCEP capital costs but lower in the following ten year period by $23.72/SWU at a 3 percent p.a. differential power cost escalation rate. At a 1.5 percent p.a. rate, the average DOE SWU price with GCEP is higher by $6.46/SWU over the next ten year period but lower in the following ten year period by $12.91/SWU.

New Technology Sensitivity

Table 6 compares the economics and energy efficiency of alternative operating plans with and without GCEP, for 3 percent and 1.5 percent p.a. differential power cost escalation assuming Advanced Isotope Separation (AIS) technology is developed successfully in accordance with current cost estimates and is available in the mid-1990's. In these scenarios gaseous diffusion capacity is assumed to be replaced entirely by the year 2000. The cost benefits of successful AIS development are substantial as can be seen by comparing the data in Table 6 with comparable data in Tables 1 and 2. These benefits are independent of building or not building GCEP.

At a 3 percent p.a. differential power cost escalation rate, the average DOE SWU price over the next ten years is higher with GCEP by $3.63/SWU and slightly higher in the following ten year period by $0.65/SWU. The TEC with GCEP is lower by $9,132 million ($509 million discounted) but the customer cost is higher by $823 million ($527 million discounted). Continuing with GCEP results in a far more energy efficient operating plan with electrical energy savings of over 25,000 megawatt years.

At a 1.5 percent p.a. differential power cost escalation rate, the average DOE SWU price over the next twenty years is $4-5/SWU higher with GCEP. The TEC with GCEP is lower by $7,384 million but on a discounted basis the TEC is higher by $80 million. The customer cost is $2,078 million higher ($915 million discounted) with GCEP. The above shows that there is a possibility that AIS availability in the mid-1990's timeframe could make it more economical not to proceed with GCEP. However, given the current status of AIS technology development and the uncertainties therein, the likelihood of AIS availability in the mid-1990's at projected costs cannot be ascertained at this time.

Feed Cost Sensitivity

The uranium price assumed in all of the previous analyses ranged from $116.80 to $132.40/kgU in the period 1983 to 1990 and $132.40/kgU thereafter. This price was lowered to $96/kgU and cases run with and without GCEP for 3 percent and 1.5 percent p.a. differential power cost escalation. The results shown in Table 7 show that the previous determinations are not sensitive to these costs.

### IV.B.2 Early Transaction Tails Assay Increase

In view of the current depressed state of the uranium industry, the effect of raising the transaction tails assay to 0.25% U-235 as early as possible was evaluated for cases which assumed GCEP on the current schedule as well as no GCEP. Column 1 of Table 8 contains the economic and energy usage characteristics of the base case (i.e., GCEP on the current schedule with the transaction tails assay maintained at 0.2 percent through FY 1995). Column 2 contains the similar data for an operating plan which maintains GCEP on the current schedule but where the tails assay is increased to 0.25% U-235 in FY 1984. The data assume a 3 percent differential power cost escalation rate. By comparing columns 1 and 2, increasing the tails assay results in a higher average DOE SWU price of $7.20/SWU over the next ten year period and $3.00/SWU in the following ten year period. The TEC is also higher by $755 million ($802 million discounted) and customer costs are increased by $1,307 million ($590 million discounted). Maintaining GCEP on the current schedule and increasing the tails assay to 0.25% U-235 in FY 1984, however, does result in decreased energy usage of 7,410 megawatt years.

Column 3 of table 8 shows the economic and energy usage characteristics assuming no GCEP and a FY 1984 increase in transaction tails assay. This mode of operation, as compared to maintaining GCEP on the current schedule and the transaction tails assay at 0.20% through FY 1995 results in increased average DOE prices of $4.87/SWU in the next ten year period and $22.56/SWU in the following ten year period. The TEC is higher by $12,641 million ($2,211 million discounted) and the customer cost is higher by $6,903 million ($1,680 million discounted). This mode of operation is also more energy inefficient requiring almost 24,000 megawatt-years of additional electrical energy consumption.

Table 9 reevaluates the plans summarized in Table 8 assuming 1.5 percent differential power cost escalation. Maintaining GCEP on the current schedule and increasing the transaction tails assay early results in higher average DOE SWU prices of $7.34/SWU over the next ten-year period and $3.28/SWU in the following ten-year period. TEC costs are higher by $1,081 million ($929 million discounted) and customer costs are higher by $1,600 million ($691 million discounted). Cancelling GCEP and increasing tails assay early results in higher average DOE SWU prices of $3.51/SWU over the next ten-year period and $16.02/SWU over the following ten-year period. The TEC is $10,537 million higher ($1,684 million discounted) and customer cost is $4,913 million higher ($1,175 million discounted).

Table 10 summarizes the economic characteristics of the plans shown in Table 9 but assuming a uranium price of $96/kgU throughout the period. Even at this lower price, an early increase in transaction tails assay is not economically attractive. Maintaining GCEP on the current schedule and increasing the transaction tails assay early results in higher average DOE SWU prices of $7.72/SWU over the next ten-year period and $3.42/SWU in the following ten-year period. The TEC is increased by $173 million ($417 million discounted) and the customer cost is increased by $736 million ($254 million discounted). Cancelling GCEP and increasing the tails assay early results in higher average DOE prices of $3.47/SWU over the next ten-year period and $15.67/SWU over the following ten-year period. The TEC is increased by $9,289 million ($1,099 million discounted) and customer cost is $3,816 million higher ($636 million discounted).

A parametric analysis was also performed to determine what the average uranium price over the next 20 years would need to be such that the discounted TEC and discounted customer costs in the early transaction tails assay increase cases shown in Table 10 would be the same as for the base case. With GCEP on the current schedule, an average uranium price over the next 20 years of about $25 per pound $U_3O_8$ would keep the TEC indifferent and an average price of about $29 per pound $U_3O_8$ would keep the customer cost indifferent. The cancel GCEP case with an early tails assay increase would require an average uranium price of $12 per pound $U_3O_8$ over the next 20 years to keep the TEC indifferent and a $22 per pound $U_3O_8$ to keep the customer cost indifferent.

### IV.B.3 Enriched Uranium Stockpile

Table 11 summarizes the economic characteristics of operating plans developed to maintain alternative (9 and 14 million SWU) minimum stockpile levels assuming mid-civilian-low government requirements. For a low government demand case, the additional 5 million SWU inventory results in an increase in the DOE price of $0.88/SWU over the next ten-year period and $2.19/SWU for the following ten-year period. The TEC is increased by $481 million ($663 million discounted) and customer cost is increased by $871 million ($283 million discounted). For a higher government demand, the additional 5 million SWU inventory results in a higher average DOE price of $0.89/SWU in the next ten-year period and $1.73/SWU in the following ten-year period. The TEC is increased by $901 million ($662 million discounted) and customer cost is increased by $714 million ($242 million discounted).

### IV.B.4. Appropriate GDP Power Levels (Operating Plan)

Utilizing the results of the sensitivity analysis discussed above, a basic operating strategy was developed to meet projected civilian and government demands for separative work. To refine this basic strategy, three primary operating plan options were then evaluated for selection. Assumptions common to each of the plans are as follows:

- The projected demand is predicated upon the August 1981 OUEA mid-civilian projection and the August 1981 low-government demand case.
- The minimum SWU inventory level excludes the 5 million SWU "set aside" for international fuel assurance purposes. Carrying the additional inventory is costly as demonstrated in section IV.B.3 and there appears to be no desire for the U.S. to maintain such an inventory on the part of current and prospective DOE toll enrichment customers.

- The transaction tails assay is maintained at the current 0.20 percent U-235 level through FY 1995. This was demonstrated in section IV.B.2 to be highly economical. In addition, the impact on SWU price is unacceptable. It would tend to drive current and prospective DOE customers to other suppliers thus resulting in a continuing upward spiraling of the price. Furthermore, maintaining the transaction tails assay at 0.20 percent U-235 also provides a major source of flexibility to accommodate unexpected increases in demand or losses in production. The operating tails assay is increased above the 0.20 percent U-235 level, using available natural uranium inventories, as needed to prevent the enriched uranium inventory from falling below the prescribed minimum level.

- GCEP production using set IV technology on a schedule where the eight buildings are in operation by FY 1994. The set IV machine is considered to be a high confidence machine and GCEP is demonstrated in section III.B.1 to be economical in essentially all situations. Although an accelerated GCEP is more economically attractive, such a schedule requires very large added capital expenditures (i.e., $200-300 million p.a.) in the FY 1984-87 timeframe and may not be achievable given the very tight budget pressures. For this reason, an accelerated GCEP schedule is not used in the current update of the operating plan.

- Replacement of some gaseous diffusion capacity occurs in the 1990's. Notice is provided to TVA to reduce contract power deliveries by 1000 MW beginning in FY 1990.

A description of each of the three primary operating plan options is given below. The differences in the plans focus on alternative target miniuum inventory levels and near-term power schedules.

ALTERNATIVE PLAN 1 (Table 12)

This plan is the base plan used in the sensitivity analyses and assumes that the desired minimum inventory is 9 million SWU (evaluated at a 0.25% U-235 tails assay). This is the working inventory component of the minimum inventory level approved by the Assistant Secretary for Resource Applications in September 1978. In this plan, the existing gaseous diffusion plants remain at the minimum permissable operating levels (2585 MW) through FY 1984 (a reduction of 3120 MW from the level in the current FY 1984 contract). In FY's 1985 and 1986, the plants are operated at power levels which are about 665 megawatts below what is currently contractually scheduled to be delivered in those years. In FY 1987 and 1988, the plants are operated at the power levels stipulated in the contracts. Beginning in FY 1989, replacement of some gaseous diffusion plant capacity with GCEP occurs. Some overfeeding (i.e., higher tails assay operation) occurs in the FY 1985 to FY 1988 period and the minimum inventory level is achieved in FY 1985 and approximately maintained thereafter.

Alternative Plan 2 (Table 13)

This plan is similar to Plan 1 except that the minimum working inventory is more rigorously defined as no less than 90 days of the following years' demand. This definition allows the working inventory to dip below 9 million SWU's until after 2000. This lower inventory allows an additional 590 megawatts to be reduced in FY 1985 with the plants operating at the same tails assay schedule as in Plan 1.

Alternative Plan 3 (Table 14)

This plan also assumes a minimum working inventory of no less than 90 days of the following year' demand. However, in this plan, power reductions are more economically spread over the FY 1984 to 1986 period. The plants are operated at a constant power level of 4360 megawatts in that period. This level of operation assures that all gaseous diffusion plant equipment improved in the Cascade Improvement Program (CIP) will be operational. This alleviates a technical concern of equipment degradation with long-term shutdown as well as reduces the risks of plant damage due to operating the plants at levels far below their design level. Operating at a constant level also results in a higher average power utilization efficiency than operating at low and then higher levels. Thus, less total GDP power is purchased than in Plan 1 or 2. This savings amounts to 1,210 megawatt-years when compared to Plan 1 and 620 megawatt-years when compared to Plan 2. In this plan, the minimum SWU inventory is achieved in FY 1986, one year later than in the other plans.

## V. Recommended Plan

Table 15 summarizes and compares key economic and other parameters for the three primary plan options. Plan 3 is recommended as it is clearly preferrable in terms of economics, operational risk as well as near-term upside flexibility. The latter is particularly important in the event that Congress determines that the 5 million SWU "set aside" is still needed for international fuel assurance purposes. The only disadvantage of this plan is a higher budget requirement in FY 1984.

## VI. Next Steps

This plan will be used for operational purposes, congressional testimony, speeches, etc. ORO will undertake negotiations with the power suppliers to determine to what extent, if any, contract power levels can be further reduced and relief from capacity charges obtained. The current plan indicates that power equivalent to about 17 million SWU can be reduced in the FY 1984 to 1986 period. The plan should also provide the framework for long-term power procurement. ORO will provide notice as soon as possible to TVA for a 1000 megawatt reduction in its contract demand using cancellation provisions in the existing contract. Concurrently, ORO and OUEA will develop a power contracting strategy for power requirements in the 1990's when the current contracts for electric power expire.

Table 1
Comparison of Economics (83$)
Mid-Civilian - Low Government Demand
High (3%) Power Cost Escalation

| | Full GCEP Accelerated | "Base" Full GCEP No Delay | GCEP 1 Yr. Delay | GCEP 2 Yr. Delay | GCEP 4 Yr. Stretch | 2 Building GCEP | No GCEP |
|---|---|---|---|---|---|---|---|
| 1983-1992 Avg. Price ($/SWU) | 143.36 | 144.94 | 146.48 | 147.91 | 147.49 | 148.68 | 143.70 |
| 1993-2002 Avg. Price ($/SWU) | 135.04 | 136.64 | 138.73 | 140.77 | 141.72 | 157.36 | 156.37 |
| Total Enterprise Cost | | | | | | | |
| Undiscounted | 136,697M | 137,904M | 138,857M | 139,904M | 140,031M | 147,286M | 149,802M |
| Discounted @ 10% | 60,079M | 60,467M | 60,883M | 61,276M | 61,234M | 62,360M | 61,936M |
| Customer Cost | | | | | | | |
| Undiscounted | 158,822M | 159,644M | 160,613M | 161,536M | 161,758M | 166,785M | 165,168M |
| Discounted @ 10% | 65,461M | 65,795M | 66,162M | 66,502M | 66,510M | 67,736M | 66,830M |
| GDP Power Usage 1983-2002 (MW-Yr.) | 97,001 | 100,949 | 104,124 | 107,272 | 108,187 | 125,868 | 130,160 |

Note: M = millions of dollars

## Table 2
## Comparison of Economics (83$)
## Mid-Civilian - Low Government Demand
## Low (1.5%) Power Cost Escalation

| | Full GCEP No Delay | GCEP 1 Yr. Delay | 2 Building GCEP | No GCEP |
|---|---|---|---|---|
| 1983-1992 Avg. Price ($/SWU) | 140.53 | 141.88 | 143.30 | 138.05 |
| 1993-2002 Avg. Price ($/SWU) | 124.04 | 125.83 | 139.22 | 137.23 |
| **Total Enterprise Cost** | | | | |
| Undiscounted | 133,051M | 133,852M | 140,422M | 142,699M |
| Discounted @ 10% | 58,872M | 59,226M | 60,230M | 59,745M |
| **Customer Cost** | | | | |
| Undiscounted | 154,882M | 155,713M | 160,126M | 158,294M |
| Discounted @ 10% | 64,315M | 64,629M | 65,740M | 64,778M |
| **GDP Power Usage** | | | | |
| 1983-2002 (MW-Yr.) | 100,949 | 104,124 | 125,868 | 130,160 |

Note: M = millions of dollars

Table 3
Comparison of Economics (83$)
Mid-Civilian - High Government Demand
High (3%) Power Cost Escalation

| | Full GCEP Accelerated | Full GCEP No Delay | GCEP 1 Yr. Delay | 2 Building GCEP | No GCEP |
|---|---|---|---|---|---|
| 1983-1992 Avg. Price ($/SWU) | 141.62 | 143.10 | 144.65 | 146.36 | 141.56 |
| 1993-2002 Avg. Price ($/SWU) | 134.03 | 135.63 | 137.61 | 155.61 | 154.17 |
| Total Enterprise Cost | | | | | |
| Undiscounted | 138,579M | 139,736M | 140,678M | 148,904M | 150,392M |
| Discounted @ 10% | 60,980M | 61,345M | 61,755M | 63,136M | 62,761M |
| Customer Cost | | | | | |
| Undiscounted | 158,186M | 158,986M | 159,919M | 165,770M | 161,347M |
| Discounted @ 10% | 65,151M | 65,472M | 65,830M | 67,282M | 66,457M |
| GDP Power Usage 1983-2002 (MW-Yr.) | 100,148 | 104,268 | 107,300 | 128,529 | 133,907 |

Note: M = millions of dollars

## Table 4
## Comparison of Economics (83$)
## Mid-Civilian - High Government Demand
## Low (1.5%) Power Cost Escalation

| | Full GCEP No Delay | GCEP 1 Yr. Delay | 2 Building GCEP | No GCEP |
|---|---|---|---|---|
| 1983-1992 Avg. Price ($/SWU) | 138.73 | 140.07 | 141.11 | 136.18 |
| 1993-2002 Avg. Price ($/SWU) | 123.05 | 124.74 | 137.60 | 135.43 |
| **Total Enterprise Cost** | | | | |
| Undiscounted | 134,833M | 135,634M | 142,045M | 143,269M |
| Discounted @ 10% | 59,722M | 60,073M | 61,001M | 60,554M |
| **Customer Cost** | | | | |
| Undiscounted | 154,237M | 155,029M | 159,180M | 157,482M |
| Discounted @ 10% | 63,999M | 64,305M | 65,313M | 64,422M |
| **GDP Power Usage** | | | | |
| 1983-2002 (MW-Yr.) | 104,268 | 107,300 | 128,529 | 133,907 |

Note: M = millions of dollars

## Table 5
### Comparison of Economics (83$)
### Low-Civilian - Low Government Demand

| | High (3%) Power Cost Escalation | | Low (1.5%) Power Cost Escalation | |
|---|---|---|---|---|
| | Full GCEP No Delay | No GCEP | Full GCEP No Delay | No GCEP |
| 1983-1992 Avg. Price ($/SWU) | 152.60 | 147.80 | 148.58 | 142.12 |
| 1993-2002 Avg. Price ($/SWU) | 137.11 | 160.83 | 126.77 | 139.68 |
| **Total Enterprise Cost** | | | | |
| Undiscounted | 118,508M | 131,987M | 114,960M | 125,139M |
| Discounted @ 10% | 53,248M | 54,459M | 52,017M | 52,383M |
| **Customer Cost** | | | | |
| Undiscounted | 140,439M | 146,030M | 136,931M | 139,388M |
| Discounted @ 10% | 58,363M | 59,275M | 57,232M | 57,326M |
| **GDP Power Usage** | | | | |
| 1983-2002 (MW-Yr.) | 81,751 | 122,320 | 81,751 | 122,320 |

Note: M = millions of dollars

### Table 6
### Comparison of Economics (83$)
### Mid-Civilian - Low Government Demand
### AIS Available in Mid 1990's

| | High (3%) Power Cost Escalation | | Low (1.5%) Power Cost Escalation | |
|---|---|---|---|---|
| | Full GCEP No Delay | No GCEP | Full GCEP No Delay | No GCEP |
| 1983-1992 Avg. Price ($/SWU) | 147.16 | 143.53 | 143.05 | 138.11 |
| 1993-2002 Avg. Price ($/SWU) | 107.68 | 107.03 | 102.62 | 98.37 |
| Total Enterprise Cost | | | | |
| Undiscounted | 132,066M | 141,198M | 129,489M | 136,873M |
| Discounted @ 10% | 59,340M | 59,849M | 58,304M | 58,224M |
| Customer Cost | | | | |
| Undiscounted | 151,237M | 150,414M | 148,800M | 146,722M |
| Discounted @ 10% | 64,086M | 63,559M | 63,140M | 62,225M |
| GDP Power Usage 1983-2002 (MW-Yr.) | 74,831 | 100,548 | 74,831 | 100,548 |

Note: M = millions of dollars

## Table 7
## Comparison of Economics (83$)
## Mid-Civilian - Low Government Demand
## Low Uranium Price

| | High (3%) Power Cost Escalation | | Low (1.5%) Power Cost Escalation | |
|---|---|---|---|---|
| | Full GCEP No Delay | No GCEP | Full GCEP No Delay | No GCEP |
| 1983-1992 Avg. Price ($/SWU) | 144.07 | 142.52 | 139.66 | 136.87 |
| 1993-2002 Avg. Price ($/SWU) | 136.24 | 155.56 | 123.65 | 136.43 |
| Total Enterprise Cost | | | | |
| Undiscounted | 114,298M | 125,526M | 109,446M | 118,421M |
| Discounted @ 10% | 51,354M | 52,625M | 49,759M | 50,433M |
| Customer Cost | | | | |
| Undiscounted | 135,861M | 140,853M | 131,100M | 133,981M |
| Discounted @ 10% | 56,555M | 57,400M | 55,077M | 55,351M |
| GDP Power Usage | | | | |
| 1983-2002 (MW-Yr.) | 100,949 | 130,160 | 100,949 | 130,160 |

Note: M = millions of dollars

Table 8
Comparison of Economics (83$)
Mid-Civilian - Low Government Demand
Raising Transaction Tails Assay Early (1984)
High (3%) Power Cost Escalation

|  | Full GCEP | Full GCEP Raise Tails | No GCEP Raise Tails |
|---|---|---|---|
| 1983-1992 Avg. Price ($/SWU) | 144.94 | 152.14 | 149.81 |
| 1993-2002 Avg. Price ($/SWU) | 136.64 | 139.64 | 159.20 |
| Total Enterprise Cost |  |  |  |
| Undiscounted | 137,904M | 138,659M | 150,545M |
| Discounted @ 10% | 60,467M | 61,269M | 62,678M |
| Customer Cost |  |  |  |
| Undiscounted | 159,644M | 160,951M | 166,547M |
| Discounted @ 10% | 65,795M | 66,385M | 67,475M |
| GDP Power Usage |  |  |  |
| 1983-2002 (MW-Yr.) | 100,949 | 93,539 | 124,867 |

Note: M = millions of dollars

### Table 9
### Comparison of Economics (83$)
### Mid-Civilian - Low Government Demand
### Raising Transaction Tails Assay Early (1984)
### Low (1.5%) Power Cost Escalation

| | Full GCEP | Full GCEP Raise Tails | No GCEP Raise Tails |
|---|---|---|---|
| 1983-1992 Avg. Price ($/SWU) | 140.53 | 147.87 | 144.04 |
| 1993-2002 Avg. Price ($/SWU) | 124.04 | 127.32 | 140.06 |
| Total Enterprise Cost | | | |
| Undiscounted | 133,051M | 134,132M | 143,588M |
| Discounted @ 10% | 58,872M | 59,801M | 60,556M |
| Customer Cost | | | |
| Undiscounted | 154,882M | 156,482M | 159,795M |
| Discounted @ 10% | 64,315M | 65,006M | 65,490M |
| GDP Power Usage | | | |
| 1983-2002 (MW-Yr.) | 100,949 | 93,539 | 124,867 |

Note: M = millions of dollars

### Table 10
### Comparison of Economics (83$)
### Mid-Civilian - Low Government Demand
### Raising Transaction Tails Assay Early (1984)
### Low (1.5%) Power Cost Escalation
### Low Uranium Price

| | Full GCEP No Delay | Full GCEP No Delay Raise Tails | No GCEP Raise Tails |
|---|---|---|---|
| 1983-1992 Avg. Price ($/SWU) | 139.66 | 147.38 | 143.13 |
| 1993-2002 Avg. Price ($/SWU) | 123.67 | 127.09 | 139.34 |
| Total Enterprise Cost | | | |
| Undiscounted | 109,446M | 109,619M | 118,735M |
| Discounted @ 10% | 49,759M | 50,176M | 50,858M |
| Customer Cost | | | |
| Undiscounted | 131,100M | 131,836M | 134,916M |
| Discounted @ 10% | 55,077M | 55,331M | 55,713M |
| GDP Power Usage | | | |
| 1983-2002 (MW-Yr.) | 100,949 | 93,539 | 124,867 |

Note: M = millions of dollars

## Table 11
Comparison of Economics (83$)
Mid-Civilian - Low and High Government Demands
14 MSWU - 9 MSWU Inventory Sensitivity
High (3%) Power Cost Escalation

| | Low Government | | High Government | |
|---|---|---|---|---|
| | Full GCEP 9 MSWU | Full GCEP 14 MSWU | Full GCEP 9 MSWU | Full GCEP 14 MSWU |
| 1983-1992 Avg. Price ($/SWU) | 144.94 | 145.82 | 143.10 | 143.99 |
| 1993-2002 Avg. Price ($/SWU) | 136.64 | 138.83 | 135.63 | 137.36 |
| Total Enterprise Cost | | | | |
| Undiscounted | 137,904M | 138,385M | 139,736M | 140,637M |
| Discounted @ 10% | 60,467M | 61,130M | 61,345M | 62,007M |
| Customer Cost | | | | |
| Undiscounted | 159,644M | 160,515M | 158,986M | 159,700M |
| Discounted @ 10% | 65,795M | 66,078M | 65,472M | 65,714M |
| GDP Power Usage | | | | |
| 1983-2002 (MW-Yr.) | 100,949 | 104,582 | 104,268 | 106,070 |

Note: M = millions of dollars

Table 12

OPERATING PLAN I SUMMARY

| | FY 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRODUCTION ($10^6$ SWU) | | | | | | | | | | | | | | |
| GDP[1/] | 9.8 | 9.8 | 9.8 | 21.0 | 21.0 | 23.3 | 23.7 | 23.0 | 23.0 | 19.0 | 19.0 | 19.0 | 19.0 | 16.6 |
| GCEP | | | | | | | .4 | 1.1 | 3.0 | 5.1 | 7.1 | 9.4 | 11.5 | 12.7 |
| TOTAL | 9.8 | 9.8 | 9.8 | 21.0 | 21.0 | 23.3 | 24.1 | 24.1 | 26.0 | 24.1 | 26.1 | 28.4 | 30.5 | 29.3 |
| TAILS ASSAYS (%) | | | | | | | | | | | | | | |
| OPERATING | .20 | .20 | .20 | .235 | .225 | .225 | .23 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| TRANSACTION | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| REQUIREMENTS ($10^6$ SWU) | | | | | | | | | | | | | | |
| @OPERATING TAILS | 15.2 | 15.3 | 20.0 | 22.0 | 19.7 | 22.9 | 25.1 | 23.7 | 25.4 | 24.9 | 26.1 | 28.9 | 29.0 | 30.8 |
| @TRANSACTION TAILS | 15.2 | 15.3 | 20.0 | 24.1 | 20.9 | 24.2 | 26.9 | 23.7 | 25.4 | 24.9 | 26.1 | 28.9 | 29.0 | 30.8 |
| SWU INVENTORY[2/] ($10^6$ SWU) | | | | | | | | | | | | | | |
| @0.25% TAILS | 23.6 | 18.7 | 9.7 | 8.7 | 9.9 | 10.3 | 9.4 | 9.8 | 10.3 | 9.6 | 9.6 | 9.2 | 10.5 | 9.2 |
| @0.20% TAILS | 26.7 | 21.1 | 10.9 | 9.8 | 11.2 | 11.7 | 10.6 | 11.1 | 11.7 | 10.9 | 10.9 | 10.4 | 11.9 | 10.4 |
| FEED INVENTORY[3/] ($10^3$ MTU) | 36.5 | 42.2 | 50.1 | 38.6 | 32.4 | 25.0 | 19.2 | 16.0 | 12.6 | 11.7 | 10.1 | 8.7 | 5.9 | 6.2 |
| OPERATING POWER (MW) | 2660 | 2660 | 2660 | 5815 | 5815 | 6560 | 6635 | 6390 | 6400 | 5225 | 5225 | 5225 | 5225 | 4725 |

NOTES

1/ ASSUMES 4% POWER NON-AVAILABILITY REDUCTION WHEN ABOVE PEM MINIMUM LEVEL (i.e., 4360 MW).

2/ MINIMUM SWU INVENTORY TARGET IS 9 MILLION SWU AT 0.25% TAILS ASSAY.

3/ FEED IN EXCESS OF WORKING INVENTORY NEEDS.

Table 13

OPERATING PLAN 2 SUMMARY

| | FY 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRODUCTION ($10^6$ SWU) | | | | | | | | | | | | | | |
| GDP1/ | 9.8 | 9.8 | 9.8 | 19.0 | 21.0 | 23.3 | 23.7 | 23.0 | 23.0 | 19.0 | 19.0 | 19.0 | 19.0 | 16.6 |
| GCEP | | | | | | | .4 | 1.1 | 3.0 | 5.1 | 7.1 | 9.4 | 11.5 | 12.7 |
| TOTAL | 9.8 | 9.8 | 9.8 | 19.0 | 21.0 | 23.3 | 24.1 | 24.1 | 26.0 | 24.1 | 26.1 | 28.4 | 30.5 | 29.3 |
| TAILS ASSAYS (%) | | | | | | | | | | | | | | |
| OPERATING | .20 | .20 | .20 | .235 | .225 | .225 | .23 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| TRANSACTION | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| REQUIREMENTS ($10^6$ SWU) | | | | | | | | | | | | | | |
| @OPERATING TAILS | 15.2 | 15.3 | 20.0 | 22.0 | 19.7 | 22.9 | 25.1 | 23.7 | 25.4 | 24.9 | 26.1 | 28.9 | 29.0 | 30.8 |
| @TRANSACTION TAILS | 15.2 | 15.3 | 20.0 | 24.1 | 20.9 | 24.2 | 26.9 | 23.7 | 25.4 | 24.9 | 26.1 | 28,9 | 29.0 | 30.8 |
| SWU INVENTORY2/ ($10^6$ SWU) | | | | | | | | | | | | | | |
| @0.25% TAILS | 23.6 | 18.7 | 9.7 | 6.7 | 8.0 | 8.4 | 7.5 | 7.9 | 8.4 | 7.7 | 7.7 | 7.2 | 8.5 | 7.2 |
| @0.20% TAILS | 26.7 | 21.1 | 10.9 | 7.6 | 9.0 | 9.5 | 8.4 | 8.9 | 9.5 | 8.7 | 8.7 | 8.2 | 9.7 | 8.2 |
| FEED INVENTORY3/ ($10^3$ MTU) | 36.5 | 42.2 | 50.4 | 41.6 | 35.4 | 28.0 | 22.3 | 19.1 | 15.7 | 14.7 | 13.1 | 11.7 | 8.9 | 9.3 |
| OPERATING POWER (MW) | 2660 | 2660 | 2660 | 5225 | 5815 | 6560 | 6635 | 6390 | 6400 | 5225 | 5225 | 5225 | 5225 | 4725 |

NOTES
1/ ASSUMES 4% POWER NON-AVAILABILITY REDUCTION WHEN ABOVE PEM MINIMUM LEVEL (i.e., 4360MW).
2/ MINIMUM SWU INVENTORY IS AT LEAST 1/4 OF FOLLOWING YEARS' DEMAND.
3/ FEED IN EXCESS OF WORKING INVENTORY NEEDS.

## Table 14

### OPERATING PLAN 3 SUMMARY

| | FY 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRODUCTION ($10^6$ SWU) | | | | | | | | | | | | | | |
| GDP 1/ | 9.8 | 9.8 | 16.7 | 16.7 | 16.7 | 23.3 | 23.7 | 23.0 | 23.0 | 19.0 | 19.0 | 19.0 | 19.0 | 16.6 |
| GCEP | | | | | | | .4 | 1.1 | 3.0 | 5.1 | 7.1 | 9.4 | 11.5 | 12.7 |
| TOTAL | 9.8 | 9.8 | 16.7 | 16.7 | 16.7 | 23.3 | 24.1 | 24.1 | 26.0 | 24.1 | 26.1 | 28.4 | 30.5 | 29.3 |
| TAILS ASSAYS (%) | | | | | | | | | | | | | | |
| OPERATING | .20 | .20 | .20 | .235 | .225 | .225 | .23 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| TRANSACTION | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| REQUIREMENTS ($10^6$ SWU) | | | | | | | | | | | | | | |
| @OPERATING TAILS | 15.2 | 15.3 | 20.0 | 22.0 | 19.7 | 22.9 | 25.1 | 23.7 | 25.4 | 24.9 | 26.1 | 28.9 | 29.0 | 30.8 |
| @TRANSACTION TAILS | 15.2 | 15.3 | 20.0 | 24.1 | 20.9 | 24.2 | 26.9 | 23.7 | 25.4 | 24.9 | 26.1 | 28.9 | 29.0 | 30.8 |
| SWU INVENTORY 2/ ($10^6$ SWU) | | | | | | | | | | | | | | |
| @0.25% TAILS | 23.6 | 18.7 | 15.8 | 10.6 | 7.8 | 8.2 | 7.3 | 7.7 | 8.2 | 7.5 | 7.5 | 7.1 | 8.4 | 7.0 |
| @0.20% TAILS | 26.7 | 21.1 | 17.8 | 12.0 | 8.8 | 9.3 | 8.2 | 8.7 | 9.3 | 8.5 | 8.5 | 8.0 | 9.5 | 8.0 |
| FEED INVENTORY 3/ ($10^6$ MTU) | 36.5 | 41.1 | 41.8 | 36.8 | 36.1 | 28.7 | 23.0 | 19.8 | [illegible] | 15.4 | 13.9 | 12.4 | 9.6 | 10.0 |
| OPERATING POWER (MW) | 2660 | 2660 | 4360 | 4360 | 4360 | 6560 | 6635 | 6390 | 6400 | 5225 | 5225 | 5225 | 5225 | 4725 |

NOTES
1/ ASSUMES 4% POWER NON-AVAILABILITY REDUCTION WHEN ABOVE PEM MINIMUM LEVEL (i.e., 4360MW).
2/ MINIMUM SWU INVENTORY IS AT LEAST 1/4 OF FOLLOWING YEARS' DEMAND.
3/ FEED IN EXCESS OF WORKING INVENTORY NEEDS.

## Table 15

## COMPARISION OF ALTERNATIVE OPERATING PLAN SCENARIOS

| Operating Plan Description | 10-Year Average SWU Charge* (1983 dollars) | Total Enterprise Cost** ($ millions) | Customer Cash Outflow** ($ millions) | Operational Risk | Near-Term Upside Flexibility |
|---|---|---|---|---|---|
| Maintain 9 million SWU inventory. Reduce production in 1984 to minimum operational level. | 140.53/124.04 | 58,872 | 64,315 | greater | greater |
| Maintain inventory of no less than one-quarter of following years' requirements. Reduce production in 1984 to minimum operational level. | 140.22/123.33 | 58,768 | 64,220 | greatest | least |
| Same as Plan 2, but maintain near-term power levels so that all improved GDP cells are fully operational. | 139.82/123.10 | 58,673 | 64,151 | least | greatest |

---

The numbers in this column indicate 1983-1992/1993-2002 average SWU prices (assuming 1.5% differential power cost escalation).

1983 dollars discounted at 10% p.a. with 1.5% differential power cost escalation.

Question 12.a. Provide detailed objectives, justifications, funding levels, and milestones for each of the activities to be funded by the FY 1983 request of $73,400,000 for the gas centrifuge process development and demonstration task categories (i.e., Basic Studies, Materials Development, Development Facility Operations, Process Equipment Development, Baseline Machine, and Advanced Machine Development).

b. Provide a detailed breakdown of FY 1982 expenditures for gas centrifuge process development and demonstration estimated to total $76,000,000 and justification of increases in the FY 1983 request.

Answer 12.a. & b The goals of gas centrifuge development and demonstration program are to demonstrate the gas centrifuge technology required for GCEP, develop centrifuges of increased efficiency for incorporation in the long-term operation of GCEP, and develop enhanced understanding of the basic phenomena associated with the centrifuge process for uranium enrichment. The majority of the FY 1983 funding is applied to the advanced gas centrifuge development and to the operation of development test facilities.

The requested funding provides for the continuation of basic development tasks; operation of existing facilities to obtain quantitative data on reliability, availability, and maintainability; and support of a construction project designed to provide capability for testing and verification of the advanced gas centrifuge design, and development of improved centrifuge performance. Whereas, the primary thrust of the development program is to provide qualified designs for the centrifuge and supporting components to be used in GCEP, this emphasis continues to shift toward improvements in centrifuge performance through the advanced gas centrifuge program. The improved machines will be used as replacement centrifuges in GCEP and for installation in later GCEP buildings.

The advanced gas centrifuge program is aimed at decreasing GCEP separative work costs by up to 50 percent. Improvements are to be achieved through the progression of three machine designs, designated Set IV, Set V, and Set VI (Set III is the baseline GCEP design). Set IV technology will achieve a 50 percent improvement in separative capacity, relative to the baseline GCEP machine, in 1985, and will be qualified for production in 1988. Set V technology provides for a 75 percent improvement in separative capacity, relative to Set III, in 1990, and will be qualified for production in 1993. Set VI technology will achieve a 100 percent improvement in separative capacity, relative to Set III, in 1995, and will be qualified for production in 1998.

The centrifuge program places increasing responsibility upon industry for product improvement activities intended to reduce the cost of the baseline centrifuge for GCEP.

Task categories covering the major aspects of the development program have been defined to reflect the current program objectives. Detailed inforamtion on the major activities within these categories is as follows:

## Basic Studies

Centrifuge physics investigations have developed a technology base necessary for long-term operation of centrifuges and for projections of future advanced machine performance improvements. However, the theory necessary to guide future improvements and to identify areas for further exploration to optimize centrifuge performance requires continuous development. Investigations will be conducted on the most promising machine and cascade design, on improved efficiency of operation through an optimization of gas flow, and on creating and modifying computer models to simulate operating phenomena within the centrifuge. The gas centrifuge theory consultants group will continue periodic assessments of the state-of-the-art and assure continued feedback to all program participants. A key element of the FY 1982 program is the identification of innovative techniques for directing flow within the centrifuge. Particular emphasis will be placed on experimental verification of such techniques in FY 1983.

## Materials Development

Materials to be used in GCEP machines are well characterized and proven for use. However, assessment of the impact of operating environments and development of improved materials will extend machine lifetime and contribute to the development of the improved machines. Activities will include characterization of the stress life and creep characteristics of the baseline and advanced centrifuge materials and evaluation of failure mechanisms resulting from shortened stress life. Machine failures will be diagnosed by examination of centrifuges removed from the Advanced Equipment Test Facility, Centrifuge Plant Demonstration Facility, and development facilities so as to identify and categorize failure mechanisms. Nondestructive rotor evaluation methods will be further developed. The compatibility of candidate advanced centrifuge and alternate baseline machine materials with uranium hexafluoride will be determined to understand chemical attack mechanisms and their contribution to mechanical failures of centrifuge components. Accelerated test techniques will be investigated that will permit short-term predictions of failures that may be expected in centrifuge rotating components during their plant life. In FY 1982, we initiated the screening of advanced materials for classified applications in the gas centrifuge.

This screening will continue in FY 1983 with the intent of identifying the most promising candidates for more detailed testing.

## Development Facility Operations

Vital data obtained from the operation of test facilities will be collected and evaluated for input to support the continuing GCEP construction program. The major test facilities to be operated in 1983 include: (1) the Advanced Equipment Test Facility, for reliability testing of the Gas Centrifuge Enrichment Plant baseline centrifuges; (2) the Component Preparation Laboratories, for assembly operations and screening tests of centrifuges produced; (3) the Advanced Machine Development Laboratory for characterization of prototype centrifuges and for mapping of sample machines to establish limits on operating parameters; (4) the Technology Test Facility, for support of the development of advanced centrifuge machines; and (5) the Centrifuge Plant Demonstration Facility, which will contain a full cascade of baseline GCEP design centrifuge machines (full operation in 1983). In FY 1982 we will complete the restart/recycle studies in the AETF-I. It will cease operation by April 1982 and will be shut down to begin conversion of the test spaces to the Advanced Centrifuge Test Facility, which is planned to begin operation with uranium hexafluoride gas in FY 1985.

## Advanced Machine Development

The advanced centrifuge development activities in FY 1983 will be devoted to design and testing of the Set IV machine. Improved Set IV machine performance will be obtained with a higher machine operating speed and with internal flow improvements. Evaluation, development, and verification testing of advanced gas centrifuge technology will be conducted by the operating contractors and the industrial manufacturing firms chosen to produce the centrifuge machines. The centrifuge manufacturers will assume the major role for the development of the Set IV machine. Their tasks will range from design, through component testing, to fabrication and testing of full-scale Set IV prototype machines and will include manufacturing studies to reduce the costs of the Set IV centrifuge design. In FY 1982, we will emphasize the potential features of the Set IV that will increase performance. By the end of FY 1982 we will select those features with greatest promise. Demonstration of their performance characteristics will occur in FY 1983 through a fully integrated demonstration centrifuge.

Question 13: Provide the detailed operating plans, including FY 1982 and FY 1983 funding levels for the following test facilities: 1) the Advanced Equipment Test Facility, 2) the Component Preparation Laboratories, 3) the Technology Test Facility, and 4) the Centrifuge Plant Demonstration Facility.

Answer 13: Advanced Equipment Test Facility (AETF)

Funding Levels: FY 1982 $3,600,000 FY 1983 $3,500,000

Half of this facility, AETF-II, is being used to demonstrate the operability and reliability of the Plc baseline centrifuge machine that will be installed in GCEP and to verify the design adequacy of that machine. Testing began prior to FY 1982 and the facility will continue operating through FY 1983 in a steady-state mode simulating the GCEP conditions in order to obtain sufficient operating time to establish reliability data.

The other half of this facility, AETF-I, will be shut down during FY 1982. This facility has established the operating parameters of the GCEP prototype machine including data relative to the restart/recycle and defect effects on the reliability and operability of the prototype centrifuge. This portion of AETF will be modified to accommodate reliability testing of the advanced Set IV centrifuge. Considerable savings will be realized by modifying this facility rather than constructing a new facility for advanced machine reliability testing.

Component Preparation Laboratories (CPL)

Funding Levels: FY 1982 $4,700,000 FY 1983 $6,400,000

The CPL is an essential support facility that provides the necessary assembly and recycle operations and screening tests in support of baseline machine operations in operating facilities such as Advanced Equipment Test Facility. The funding increase in FY 1983 provides for the support, including assembling replacement machines, of the Centrifuge Plant Demonstration Facility, which begins operation that year. Funding for this facility provides for basic maintenance, production control, technical support, and management to sustain the recycle assembly area operation.

Technology Test Facility (TTF)

Funding Levels: FY 1982 $280,000 FY 1983 $1,600,000

This project will provide facilities and equipment to support the development of advanced gas centrifuge machines. Included are equipment for component and machine assembly and material testing; test stands for rotor balancing; and capability for advanced cascade process tests.

Question 14.a. Provide detailed objectives, justifications, funding levels and milestones for each of the activities to be funded by the FY 1983 request of $12,800,000 for gas centrifuge supporting services.

Answer 14.a. The gas centrifuge supporting services provides for the funding to implement startup pocedures and personnel training for GCEP operations. GCEP startup and operational procedures cover such activities as preparation of all operations and maintenance procedures, preparation of all integrated systems tests procedures, preparation of training manuals for production and maintenance, training of operating and maintenance personnel, and the performance of integrated process system tests. The GCEP startup activity is geared into operational milestones that are based on installation of service modules into the first operational train in Process Building #1 by October 1982, beneficial occupancy date for the first train by July 1983, first production machine installed in Process Building #1 by January 1984 and first cascade on process gas by April 1984. Training, facility procedures, system testing, etc. are integrated into a startup plan to meet these milestone dates which support full operation of Process Building No. 1 by June 1988. Funding levels for this activity are provided below:

| | (dollars in thousands) |
|---|---|
| Operating Personnel | 8,991 |
| Operating/Maintenance Materials | 2,861 |
| GDP Support Costs | 648 |
| DOE Direct Support | 300 |
| | 12,800 |

Question 14.b. Provide a detailed breakdown of FY 1982 expenditures for gas centrifuge supporting services activities estimated to total $5,200,000 and justifications for increases in the FY 1983 request.

Answer 14.b. A funding breakdown for the FY 1982 expenditures for gas centrifuge supporting services is provided below:

| | (dollars in thousands) |
|---|---|
| Operating Personnel | 3,588 |
| Operating/Maintenance Materials | 1,202 |
| GDP Support | 310 |
| DOE Direct Support | 100 |
| | 5,200 |

Major increases in the FY 1983 level as compared to FY 1982 reflects the buildup of operational, maintenance and support personnel necessary to meet the startup milestones of the program (first centrifuge machine installed in January 1984). GCEP startup manpower increases from 86 in FY 1982 to 228 in FY 1983.

Funding in FY 1982 provides for the initial operational checkout and startup of the TTF. Funding in FY 1983 is for final operational checkout and initial screening of the Set IV prototype machine.

### Centrifuge Plant Demonstration Facility (CPDF)

Funding Levels: FY 1982 $5,200,000 FY 1983 $5,200,000

The purpose of the CPDF, which is scheduled for start-up in late 1982, is to demonstrate the producibility, constructability, and operability of the equipment designs that will be used for the GCEP. The CPDF will consist of one of the basic building blocks of the GCEP--a unit cascade--and will use the same centrifuge machines and essentially the same support facilities planned for the GCEP.

Experience gained from CPDF construction and operation will verify that centrifuge machines manufactured by industry meet GCEP operational requirements and will demonstrate design, construction, and operating criteria for the GCEP. The methods and procedures involved in the installation, start-up, maintenance, and general daily operation of a production centrifuge cascade will be determined, and experience will be gained in the methodology for the training of GCEP operating personnel.

After cascade operability is demonstrated, cascade performance will be evaluated against GCEP cascade requirements. The cascade and its ancillary equipment will be sufficiently flexible to accommodate the industry-supplied centrifuges and the support and process systems used in the testing and continued development of a unit cascade.

FY 1982 funds are provided to develop operating procedures, conduct facility systems assurance tests, continue personnel training, and prepare for start-up. The funds in FY 1983 are for continuous operation and demonstration of the GCEP unit cascade.

Question 15. Provide detailed justification, funding levels, and a priority listing for the FY 1983 request of $3,800,000 for gas centrifuge operations and support capital equipment.

Answer 15. The amount requested provides $1,150,000 for replacement of equipment (general laboratory and test equipment) in operating facilities that has exceeded its useful life in support of ongoing test activities. New or additional equipment amounting to $2,200,000 is needed in support of development and/or test activities conducted in baseline centrifuge facility operations, in the advanced gas centrifuge effort, and in basic studies. This includes diagnostic equipment, fabrication equipment for advanced materials, and general laboratory and analytical equipment. Automatic data processing equipment used to gather and manipulate data from operating facilities and modeling of machine performance amounts to $450,000.

This request of $3,800,000 represents the minimum needed to support the FY 1983 gas centrifuge development activities in support of GCEP. The sum was reached by selecting only the highest priority equipment needed by our operating contractors to perform required tasks.

Question 16. Why is $4,500,000 required for Project 82-R-418 in FY 1983? Why can't the funds be provided over a period of two or more years?

Answer 16. Project 82-R-418 is the Advanced Centrifuge Test Facility and will be used to establish the reliability of the advanced gas centrifuge, Set IV, machine design.

This project as originally proposed was estimated to cost $25,000,000 but because of revisions to the advanced centrifuge development program, in an effort to reduce costs, this project was reduced in scope. The current total cost is estimated to be $7,000,000 and $4,500,000 is the minimum required in FY 1983 to maintain the project schedule. This schedule supports having Set IV centrifuge machines in Process Buildings No. 3-8 of GCEP. The Set IV machines will also be backfitted as replacements, in Process Buildings No. 1 & 2.

Question 17. Provide the Subcommittee with the latest update of the following information with regard to Project 76-8-g, the Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio:

Answer 17.a. thru s. are on the following pages.

Question 17.a. Principal DOE prime contracts;

Answer 17.a. The following is a list of the prime contracts for the GCEP and their location.

ARCHITECT-ENGINEERS

Catalytic, Inc.
Phildaelphia, Pennsylvania

Fluor Engineers and Constructors, Inc.
Irvine, California

Bechtel National, Inc.
San Francisco, California

Commonwealth Associates, Inc.
Jackson, Michigan

SYSTEMS SUPPORT CONTRACTOR

Systems Development Corporation/Daniel,
Mann, Johnson & Mendenhall
Santa Monica, California

CONSTRUCTION MANAGER/CONSTRUCTOR

Stone and Webster Engineering Corp.
Boston, Massachusetts

OPERATING CONTRACTORS

Union Carbide Corp. - Nuclear Div.
Oak Ridge, Tennessee

Goodyear Atomic Corp.
Waverly, Ohio

AiResearch Manufacturing Company
Torrance, California

CENTRIFUGE MANUFACTURERS

Boeing Engineering and Construction Company
Oak Ridge, Tennessee

Garrett Corporation
Sandusky, Ohio

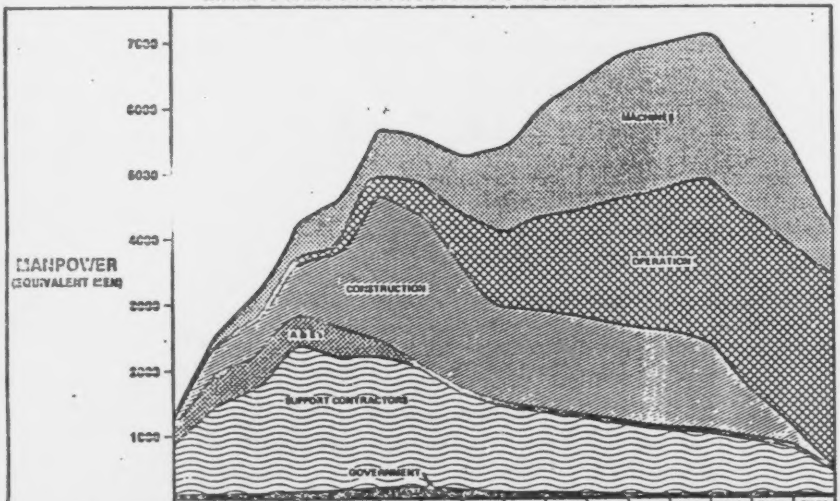
Goodyear Aerospace Corporation
Akron, Ohio

Question 17.b. Manpower projection (15 years) by function (i.e. government, support contractors, A&Es, construction, operation and machine manufacturers);

Answer 17.b. The following is a graph and table of the manpower projected to be employed by the GCEP by function for FY 1979 thru FY 1994.

## GAS CENTRIFUGE ENRICHMENT PLANT

### MANPOWER PROJECTION BY FUNCTION



| | FY 79 | FY 80 | FY 81 | FY 82 | FY 83 | FY 84 | FY 85 | FY 86 | FY 87 | FY 88 | FY 89 | FY 90 | FY 91 | FY 92 | FY 93 | FY 94 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GOVERNMENT (ORO & PAO) | 78 | 63 | 146 | 140 | 163 | 163 | 165 | 128 | 117 | 100 | 100 | 94 | 88 | 82 | 66 | 44 |
| SUPPORT CONTRACTORS* | 1333 | 1540 | 2120 | 2088 | 2097 | 1934 | 1842 | 1231 | 1316 | 1226 | 1124 | 1036 | 977 | 832 | 754 | 382 |
| ARCHITECTS & ENGINEERS | 538 | 604 | 620 | 450 | 236 | 83 | 30 | 19 | 16 | 14 | 13 | 10 | 10 | 8 | 8 | 2 |
| CONSTRUCTION (ORO & PAO) | 422 | 825 | 830 | 1100 | 2200 | 2300 | 1030 | 1900 | 1660 | 1640 | 1500 | 1080 | 1400 | 600 | 300 | 100 |
| OPERATION (PORTSMOUTH) | 0 | 5 | 19 | 81 | 278 | 438 | 773 | 1109 | 1421 | 1421 | 1883 | 2184 | 2419 | 2561 | 2812 | 2940 |
| MACHINE CONTRACTORS | 169 | 334 | 535 | 630 | 830 | 730 | 870 | 1230 | 1630 | 1870 | 2210 | 2240 | 2238 | 1930 | 1430 | 730 |
| TOTAL | 2540 | 3143 | 4231 | 4490 | 5332 | 5370 | 5305 | 5329 | 6050 | 6440 | 6850 | 7036 | 7130 | 6370 | 5324 | 4207 |

* OCPO & OC, ECC & CMC

MANPOWER FOR FY 79 & FY 80 ARE ACTUALS AT THE END OF THE FY.

MANPOWER PROJECTIONS FOR FY 81 THROUGH FY 94 ARE AVERAGE FOR THE FY.

Question 17.c. Manpower status;

Answer 17.c. The latest manpower status for the GCEP available is the January figure. This is the low point for the year due to adverse weather conditions which affect construction at the site.

## MANPOWER STATUS*
### JANUARY 1982

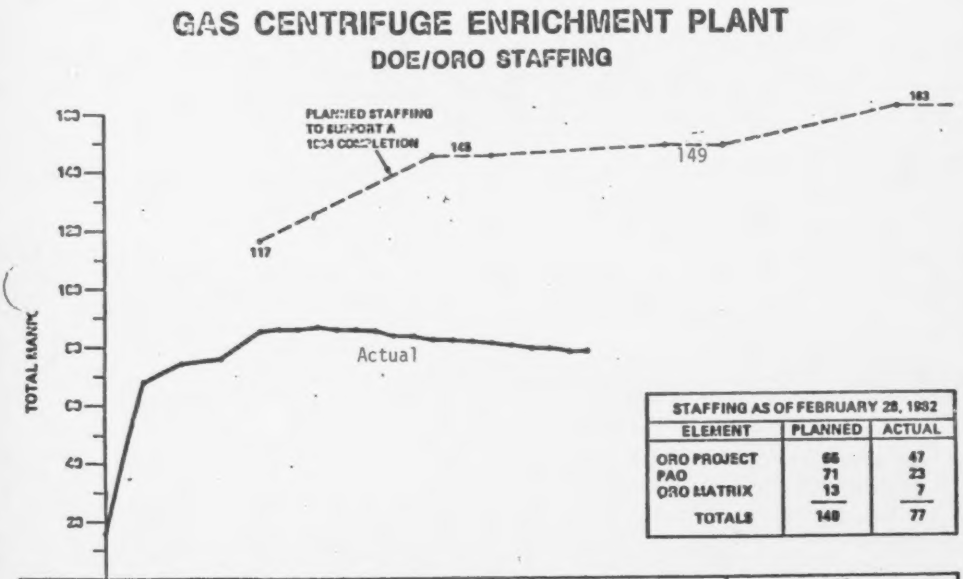
| PARTICIPANT | ACTUAL |
|---|---|
| **DEPARTMENT OF ENERGY** | |
| Oak Ridge Operations Office | 54 |
| Portsmouth Area Office | 23 |
| **ARCHITECT-ENGINEERS** | |
| Catalytic, Inc. | 71 |
| Fluor Engineers and Constructors, Inc. | 269 |
| Bechtel National, Inc. | 141 |
| Commonwealth Associates, Inc. | 4 |
| **SYSTEMS SUPPORT CONTRACTOR** | |
| SDC/DMJM | 163 |
| **CONSTRUCTION MANAGER/CONSTRUCTOR** | |
| Stone and Webster Eng. Corp. | 134 |
| **OPERATING CONTRACTORS (INCL. OCPO)** | |
| Union Carbide Corp. - Nuclear Div. | 679 |
| Goodyear Atomic Corp. | 255 |
| AiResearch Manuf. Co. | 328 |
| **** CENTRIFUGE MANUFACTURERS** | |
| Boeing Engr. and Const. Co. | 225 |
| Garrett Corp. | 100 |
| Goodyear Aerospace Corp. | 120 |
| **CONSTRUCTION CONTRACTORS** | |
| Portsmouth | 343 |
| Oak Ridge (estimated) | 25 |
| TOTAL | 2934 |

Question 17.d. DOE/ORO staffing, planned and actual;

Answer 17.d. The DOE/ORO staffing planned and actual for the GCEP project in the field is shown on the following chart.

## GAS CENTRIFUGE ENRICHMENT PLANT

### DOE/ORO STAFFING



| STAFFING AS OF FEBRUARY 28, 1982 | | |
|---|---|---|
| ELEMENT | PLANNED | ACTUAL |
| ORO PROJECT | 65 | 47 |
| PAO | 71 | 23 |
| ORO MATRIX | 13 | 7 |
| TOTALS | 149 | 77 |

| FY | 77 | 78 | 79 | 80 | 81 | | | | | | | | | | | | 82 | | | | | | | | | | | | 83 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S |
| PLANNED | – | 64 | 117 | 117 | 146 | | | | | | | | | | | | 149 | | | | | | | | | | | | 163 | | | | | | | | | | | |
| ACTUAL | 68 | 74 | 78 | 85 | 88 | 88 | 87 | 88 | 88 | 88 | 84 | 84 | 83 | 83 | 82 | 81 | 80 | 79 | 79 | 77 | 77 | | | | | | | | | | | | | | | | | | | |

Question 17.e. Status of the construction and procurement awards.

Answer 17.e. At the end of February, the plant construction and procurement were on schedule with construction at 7.6% and procurement at 3.3% of the full eight buildings. Of the first two buildings, construction was 30% and procurement 13% complete.

Question 17.f. Construction contracts awarded by PAO;

Answer 17.f. Construction contracts awarded by PAO are as follows:

1977

PAO Admin. Bldg.
Relocation Whses.

1978

Outside Utilities
Gen. & Central Receiving Whse.
Mobile Equip. Garage
So. Perimeter Rd.
Relocate Utilities
RHW, Phase I

1979

Pumping & Observation Well
Rough Grading
Fire Station
Salt Storage, Truck Scales
Warehouse Mods
Railroad to X-326
Sanitary Landfill
W. Perimeter Rd.
Structural Steel, PB # 1
Foundations & U.G. Utilities

1980

GCEP Adm. Bldg.
345 kV Substation & Switchhouse
345 kV Substation, X-530A Addition
PB #1 Early Lighting
Bldg. Shell, PB #1
Temp. Admin. Bldg
345 kV U/G Transmission
Floor Modules
Struct. Steel Foundation, U/G Utilities, PSB
R/A & CTTF Excavation, U/G Concrete & Utilities
Const. Trailor Compl. & Power
Transfer Corridor Shell & Struct. Steel
Sanitary Water for Early Fire Prot.
NE By-Pass Road
GCEP Temp. Facility

1981

Recycle Assembly Bldg Roofing and Siding
Outside Utilities
PC # 1 Internals
Process Support Bldg Roofing and Siding
PB # 2 Foundation
Cooling Tower, Pump House and Air Plant
Water Storage Tanks and Pump Station
Central Control Bldg.
PB # 2 Structural Steel
Recycle Assembly Bldg Internals

1982

Process Support Bldg Internals
Recycle Assembly Bldg. Concrete Slab
Transfer Corridor Extension
Warehouse Modification - XT847
Recycle Assembly Bldg. Cranes
Bldg Shell and Utilities for PB #2
Cooling Water Pumps

Question 17.g. Major UCC-ND GCEP subcontracts awarded to date;

Answer 17.g. The major UCC-ND subcontracts are as follows:

Cascade Isolation Valves
Purge/Evacuation Vacuum Pumps
Cascade Isolation Valve Prototypes
Rotor Disp. Meas. System
Rotor Balance Check Stand Casing Assembly
Machine Mounts
Rotor Centralizer
Mount Assemblies
Vacuum System Module
Water Trace System Module
Hardware
Control & Data Acquisition System
Vaccum System
Machine Isolation Valve Prototypes
Machine Valve Sets
Flexible Connectors
Sensor Manifold Valves
Test Prototype Machine Valve Sets
Prototype, Back Pressure Control Valves
Machine Drive Package Prototypes
Machine Variable Instrument Package Prototypes
Drum Type Shipping Container w/Dunnage
Centrifuge Plant Operator Training Simulator
Motor Operators for Valves
G-17 Bellows Assembly
Equipment for Process Control & Data System
Sample System Block Valves
Tow Tractor, Intraplant
Shear Baler
Hydraulic Power Unit & Cylinders
Rotor Cleaning Equipment
Wreck Disassembly Equipment
Spray Tunnel
Electromagnetic Interface
Diffusion Oil Pump
Diffusion Mechanism
Computer System (General)
Vibration Analysis Computer System
Biaxial Seismic Shaker
Crane, Rigid Mast
Data Acquisition System
Instrment Cabinet & Panels
Systems Interface Test Facility
Instrument Cabinets
Distributive Control System - F&W Building

| | |
|---|---|
| Question 17.h. | TEC savings derived from systems engineering; |
| Answer 17.h. | Systems engineering work on the GCEP have resulted in $68.3 million saved. This savings has been used to offset cost growth in other parts of the project. |
| Question 17.i. | TEC by percent of total project (i.e. by functional activity and by buildings and improvement); |
| Answer 17.i. | The TEC breaks down into function as follows: |

| | |
|---|---|
| Centrifuge Machine Procurement | 40% |
| Service Module Procurement | 12% |
| Technical Support | 6% |
| Engineering | 9% |
| Construction | 27% |
| Other Procurements | 6% |

The TEC in FY 1983 dollars is $6.95 billion.

The percentage of the TEC for buildings and improvements is the construction function.

| | |
|---|---|
| Question 17.j. | Financial status--planned and actual to date and planned and actual cumulative to date, and planned in FY 1982 and FY 1983. |
| Answer 17.j. | The financial status is as follows: |

| | | | FY 1982 Appropriation | | | |
|---|---|---|---|---|---|---|
| | | Cumulative Thru FY 1981 | Actual Thru February | Balance Available | Total | FY 1983 Request |
| Obligations | Planned | 948 | 550 | 38 | 588 | 613 |
| | Actual | 948 | 543 | 45 | 588 | - |

Question 17.k. Actual and planned construction awards in FY 1982 and FY 1983;

Answer 17.k. Following is a list of construction awards planned in FY 1982 and FY 1983 with dates for those awarded.

| FY 1982 | Award Dates |
|---|---|
| Process Support Bldg. Internal | 11/25 |
| R/A Storage Yard & Concrete Slab | 2/12 |
| Warehouse Modifications | 2/17 |
| Transfer Corridor Extension | 1/14 |
| Process Building #2 Shell & Utilities | Ready for Award |
| Vertical Pump Assemblies | |
| R/A Major Crane System | |
| CTTF Special Equipment Support | |
| Shell & Utilities, PB #2 | |
| RM Crane Installation, PB #1 | |
| HVAC Balance & Operation, PB #1 | |
| Feed & Withdrawal Steel/Shell | |
| R/A Special Equipment Support | |
| GCEP Computer Center | |
| Outside Utilities, Phase 1, Above-Ground Installation | |
| R/A Special Equipment Status Stand Area | |
| R/A Special Equipment Tanks | |

| FY 1983 |
|---|
| Foor Modules |
| Centrifuge Assembly |
| PB #1 Service Modules |
| R/A - CTTF Special Equip. Installation |
| Feed & Withdrawal Building |
| F&W Internals |
| Process Steam Line |
| Interplant Process Piping No. 1 |
| Distributive Control Support |
| Process Control Data Acquisition System Instr. |
| Maintenance Stores Training Bldg. |
| Outside Utilities |
| Site Improvements |
| Fire Alarm System |
| Integrated Data Management System |

Acronyms

PB - Process Building
R/A - Recycle/Assembly Building
CTTF - Centrifuge Training and Test Facility
RM - Ridgid Mast Crane
HVAC - Heating Ventilation and Air Conditioning
F&W - Feed and Withdrawal

Question 17.1. Actual and planned procurement awards in FY 1982 and FY 1983;

Answer 17.1. The planned procurement awards for FY 1982 and FY 1983 are listed.

1982

Position Checkout Device
Drive Down Carts
Operator Diagnostic Unit
$UF_6$ Feed & Dump Carts
Leak Detector Service Carts
Train Feed Control Valves
PV/EV Valves & Pumps
Cascade Isolation Valves
Vendor Surveillance/Support
First Train Instrumentation
Centrifuge Machines
Lubricating Fluid
Diffusion Pump Oil
Dimensional Functional Test Equipment

Transportation Equipment
Machine Isolation Valves
Machine Drive Package
Machine Variables Instrument Package
Back Pressure Control Valve
Sensor Manifold Valves
Vendor Surv/Supp.
Flexible Connectors

Shipping Containers
Rotor Decontamination & Cleaning Area
Column Decontamination & Cleaning Area
Wreck Disassembly Area Equipment
Gas Test Equipment
Computer System
Rotor Balance Stands
Rotor Balance Check Stands

Cascade Computer System
Training Simulator
Special Handling Equipment
Refurbish Valves
Primary Cold Traps
Tails Vent Cold Traps
1-5 Stage Compressors
Sensor Manifold Valves
Process Valves
Control Valves

1983

$UF_6$ Feed & Dump Carts
Machine Backfill Cart
Isolator Mounting Kits
Mounting Lugs
Locking Collar
Cap Screws & Springwashers
Hardware Support
Machine Installation Fixture
PV/EV Valves & Pumps
Vendor Surveillance/Support
Centrifuge Machines

Transportation equipment
Machine Isolation Valves
Machine Drive Package
Machine Variables Instrument Package
Sensor Manifold Valves

Flexible Connectors

Shipping Containers
Column Repair Area Equipment
Rotor Repair Area
Gas Test Equipment
Rotor Balance Stands

Cascade Computer System
Training Simulator
Process Valves

Product & Tails Storage Yard
Solid Waste Disposal Equipment
Guard Precinct Station Equipment
Laboratory Mod. Equipment
Fire Station Equipment
GCEP Administration Building Furnishings
Data Process Building Equipment
Warehouse
Integrated Data Management System

Answer: 17.1. - continued:

| 1982 | 1983 |
|---|---|
| Feed Burp Evacuation Cold Traps | |
| Sublimer | |
| Refrigeration System | |
| Distributed Control System | |
| Tails Condenser | |
| Accountability Track Scale | |
| Dump Scale | |
| Fill Station Scale | |
| Tails Recycle Cooler | |
| Accountability Platform Scale | |
| Process Control Data Acquisition System (PCDAS) | |
| Product Transfer Facility | |
| Sample Valves | |
| Intraplant Transporter/Tow Tractor | |
| Sample Pumps | |
| Laboratory Mod. Equipment | |
| Integrated Data Management System | |

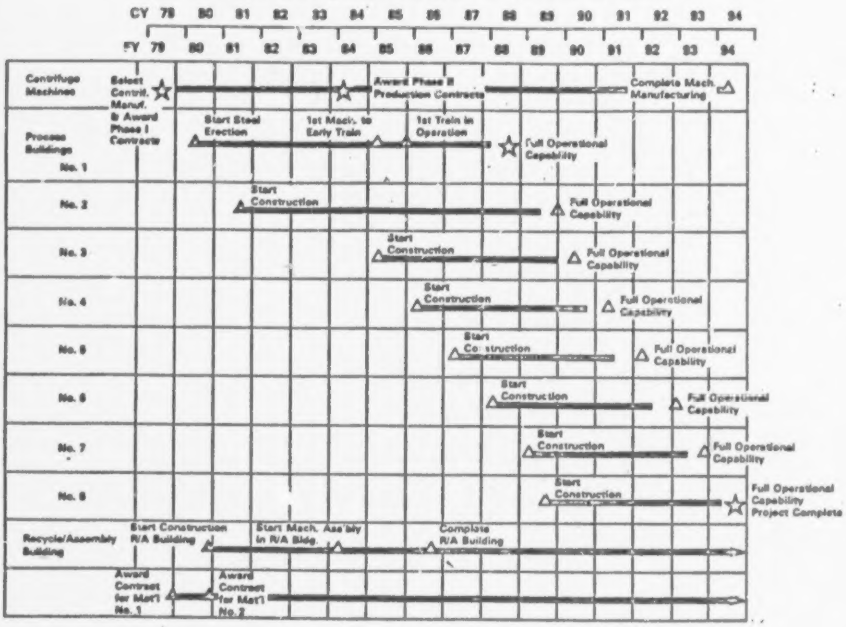
Acronyms

PV/EV - Process ventilation/exhaust ventilation
$UF_6$ - Uranium hexafluoride

Question 17.m. Latest summary schedule;

Answer 17.m. The following is the latest summary schedule.

Gas Centrifuge Enrichment Plant Schedule



Question 17.n. Actual and planned percent project completion in FY 1982 and FY 1983?

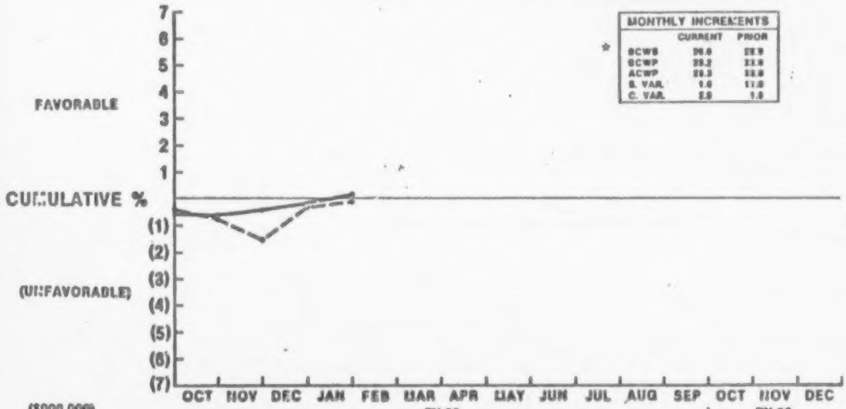
Answer 17.n. The planned percent complete of the plant is as follows:

| | 2 Buildings | 8 Buildings |
|---|---|---|
| End FY 1982 | 29% | 12% |
| End FY 1983 | 41% | 17% |

Question 17.o. Cumulative cost and percent schedule variance;

Answer 17.o. The following chart shows the January 1982 cost and schedule variance analysis for the GCEP Project.

## GAS CENTRIFUGE ENRICHMENT PLANT
### TOTAL PROJECT COST & SCHEDULE VARIANCE ANALYSIS



| MONTHLY INCREMENTS | CURRENT | PRIOR |
|---|---|---|
| * BCWS | 26.6 | 25.9 |
| BCWP | 28.2 | [illegible] |
| ACWP | 23.3 | [illegible] |
| S. VAR. | 1.6 | 11.0 |
| C. VAR. | 2.9 | 1.8 |

($000,000)

| | | OCT | NOV | DEC | JAN | FEB | MAR<br>FY 82 | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV<br>FY 83 | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | BCWS | 789.3 | 831.0 | 856.9 | 883.5 | | | | | | | | | | | |
| PERFORMED | BCWP | 783.7 | 817.5 | 854.4 | 882.8 | | | | | | | | | | | |
| ACTUAL | ACWP | 788.1 | 821.1 | 856.1 | 881.4 | | | | | | | | | | | |
| SCHEDULE VARIANCE | $ | (5.6) | (13.5) | (2.5) | (.8) | | | | | | | | | | | |
| | % | (.7%) | (1.6%) | (.3%) | (.1%) | | | | | | | | | | | |
| COST VARIANCE | $ | (4.4) | (3.6) | (1.7) | 1.2 | | | | | | | | | | | |
| | % | (.6%) | (.4%) | (.2%) | .1% | | | | | | | | | | | |

NOTE: Some Figures May Not Add Due To Rounding

CUM SCHEDULE % – – –     CUM COST % ———

---

* BCWS - Budget cost of work scheduled.
BCWP - Budget cost of work performed.
ACWP - Actual cost of work performed.

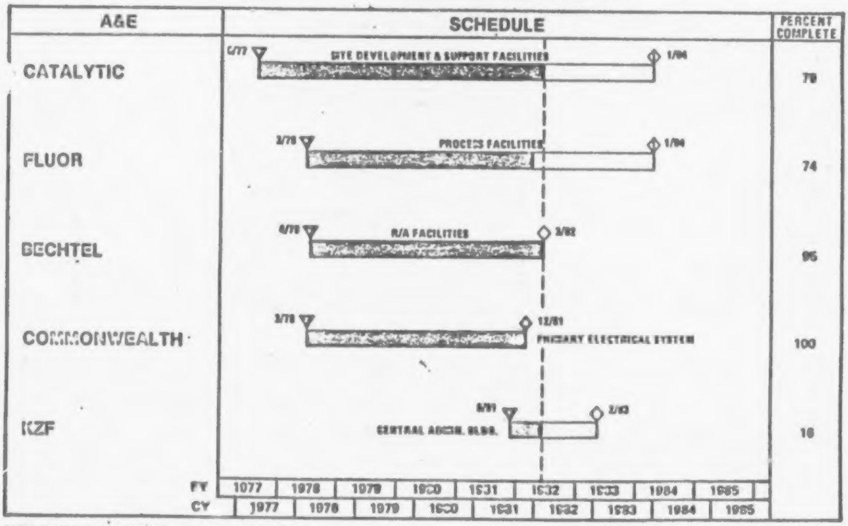
Question 17.p. A&E design status;

Answer 17.p. The status of the AE's is shown on the following chart.

## GAS CENTRIFUGE ENRICHMENT PLANT

### A & E DESIGN STATUS

### PORTSMOUTH FACILITIES SUMMARY SCHEDULE

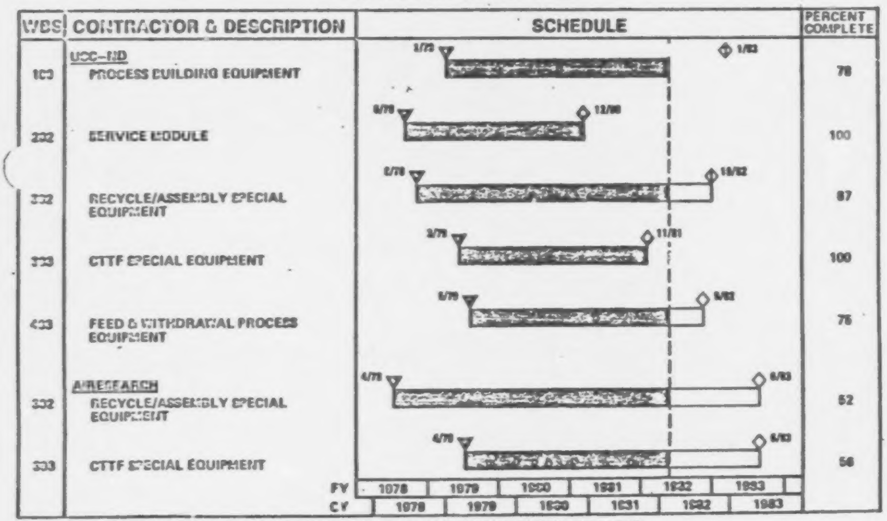


NOTE: FROM DESIGN AWARD TO COMPLETION OF TITLE II

Question 17.q. Operating contractor design status;

Answer 17.q. The operating contractor design status for the GCEP is shown on the following chart.

## GAS CENTRIFUGE ENRICHMENT PLANT
### OPERATING CONTRACTOR DESIGN STATUS
### SUMMARY SCHEDULE



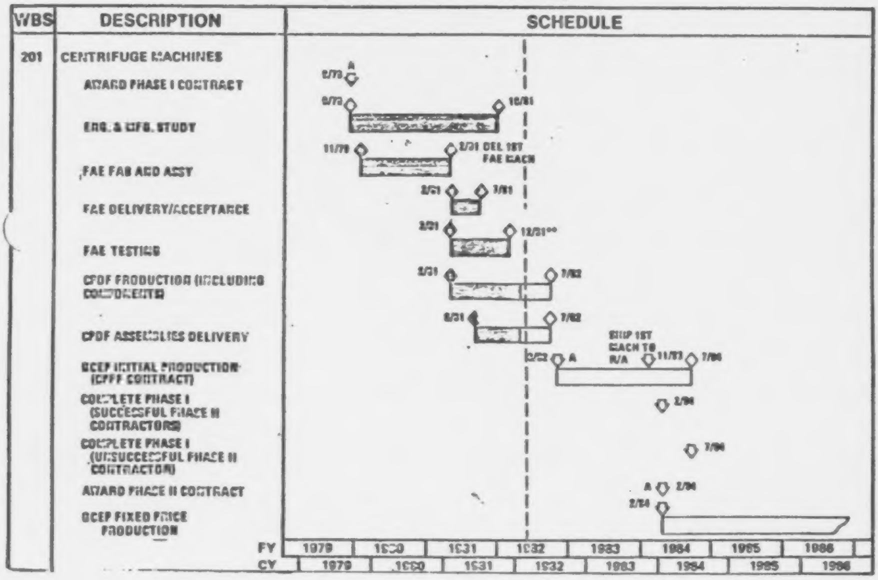
NOTE: SCHEDULE FROM DESIGN START TO DESIGN COMPLETE, INCLUDING INSTALLATION DRAWINGS, BUT NOT INCLUDING DOCUMENTATION SUCH AS O & M MANUALS, TECHNICAL STUDIES, AE DESIGN REVIEWS, TEST PLANNING, ETC.

Question 17.r. Summary procurement schedule for centrifuge machines and balance of plant;

Answer 17.r. Attached are three charts which summarize the procurement schedule for centrifuge machine and major balance of plant equipment.

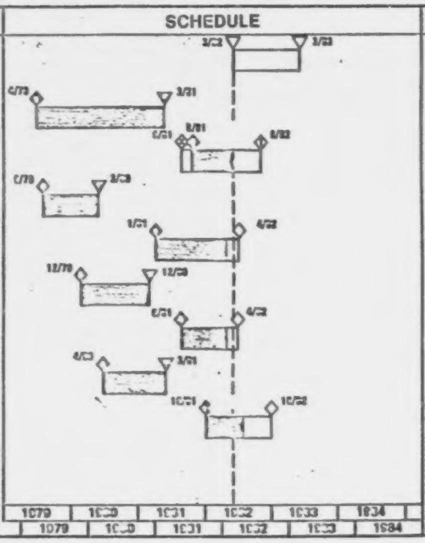
Question 17.r. - continued

## GAS CENTRIFUGE ENRICHMENT PLANT
### SUMMARY PROCUREMENT SCHEDULE (CON'T.)
### (CENTRIFUGE MACHINES)



Question 17.r. - continued

# GAS CENTRIFUGE ENRICHMENT PLANT
## SUMMARY PROCUREMENT SCHEDULE
## (BALANCE OF PLANT)

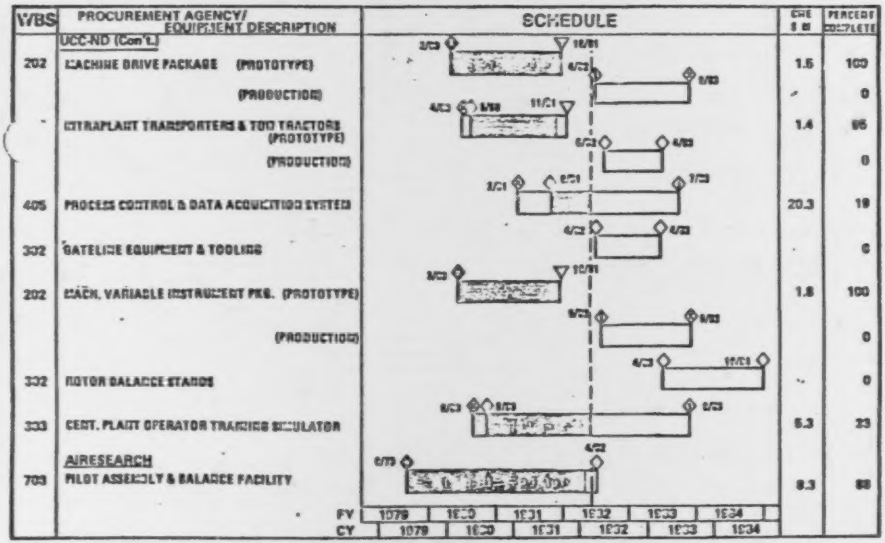


| WBS | PROCUREMENT AGENCY / EQUIPMENT DESCRIPTION | CCE $M | PERCENT COMPLETE |
|---|---|---|---|
| | GOODYEAR ATOMIC | | |
| 433 | AUTOCLAVES | | 0 |
| | UCC-ND | | |
| 1 | RIGID MAST CRANES (PROTOTYPE) | 1.0 | 100 |
| | (PRODUCTION) | 5.5 | 48 |
| 202 | MACHINE ISOLATION VALVES (PROTOTYPE) | 1.7 | 100 |
| | (PRODUCTION) | 58.7 | 87 |
| 101 | CASCADE ISOLATION VALVES (PROTOTYPE) | 0.4 | 100 |
| | (PRODUCTION) | 2.8 | 83 |
| 202 | BACK PRESSURE CONTROL VALVES (PROTOTYPE) | 0.3 | 100 |
| | (PRODUCTION) | 2.6 | 40 |

NOTE: SCHEDULE FROM AWARD THROUGH DELIVERY OF FIRST PRODUCTION ARTICLE

Question 17.r. - continued

## GAS CENTRIFUGE ENRICHMENT PLANT
### SUMMARY PROCUREMENT SCHEDULE (CON'T.)
### (BALANCE OF PLANT)

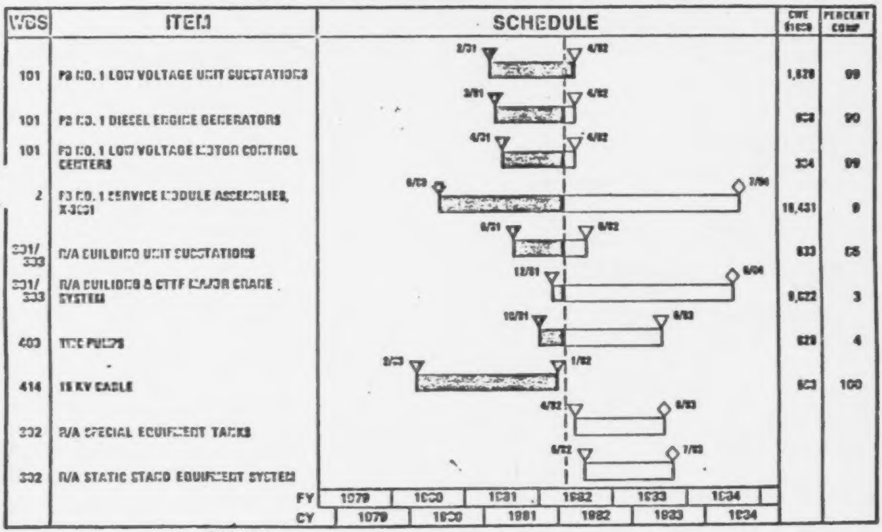


NOTE: SCHEDULE FROM AWARD THROUGH DELIVERY OF FIRST PRODUCTION ARTICLE

| | |
|---|---|
| Question 17.s. | Construction summary schedule, construction/procurement schedule, and off-site technical support facilities summary schedule by WBS category; |
| Answer 17.s. | Attached are the construction summary schedule, and off-site technical support facilities summary schedule by WBS category. |

Question 17.s. - continued

## GAS CENTRIFUGE ENRICHMENT PLANT
### CONSTRUCTION/PROCUREMENT SCHEDULE



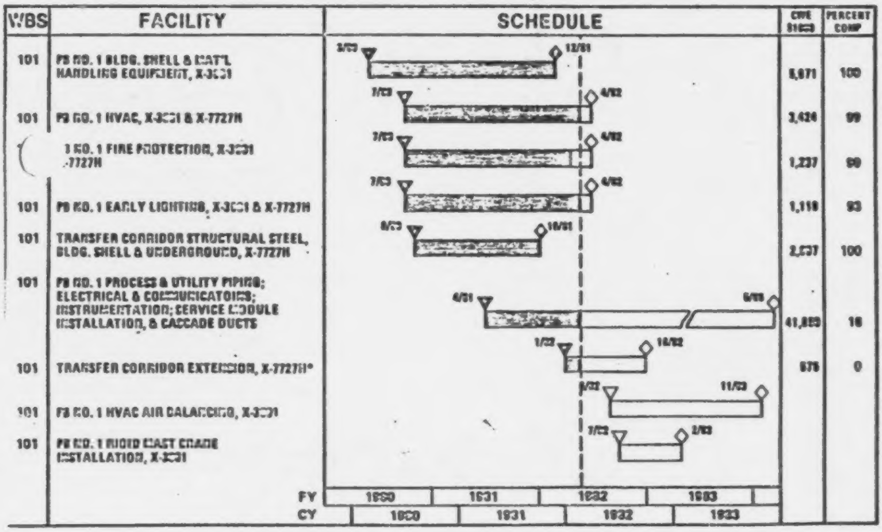
| WBS | ITEM | SCHEDULE | CWE $1000 | PERCENT COMP |
|---|---|---|---|---|
| 101 | PB NO. 1 LOW VOLTAGE UNIT SUBSTATIONS | 2/81 4/82 | 1,828 | 99 |
| 101 | PB NO. 1 DIESEL ENGINE GENERATORS | 3/81 4/82 | 603 | 90 |
| 101 | PB NO. 1 LOW VOLTAGE MOTOR CONTROL CENTERS | 4/81 4/82 | 304 | 99 |
| 2 | PB NO. 1 SERVICE MODULE ASSEMBLIES, X-3001 | 6/80 7/84 | 10,431 | 9 |
| 301/ 303 | R/A BUILDING UNIT SUBSTATIONS | 6/81 6/82 | 833 | 65 |
| 301/ 303 | R/A BUILDING & CTTF MAJOR CRANE SYSTEM | 12/81 6/84 | 9,022 | 3 |
| 403 | TWC PUMPS | 10/81 6/83 | 828 | 4 |
| 414 | 15 KV CABLE | 2/80 1/82 | 603 | 100 |
| 302 | R/A SPECIAL EQUIPMENT TANKS | 4/82 6/83 | | |
| 302 | R/A STATIC STAND EQUIPMENT SYSTEM | 6/82 7/83 | | |

FY 1979 1980 1981 1982 1983 1984
CY 1979 1980 1981 1982 1983 1984

Question 17.s. - continued

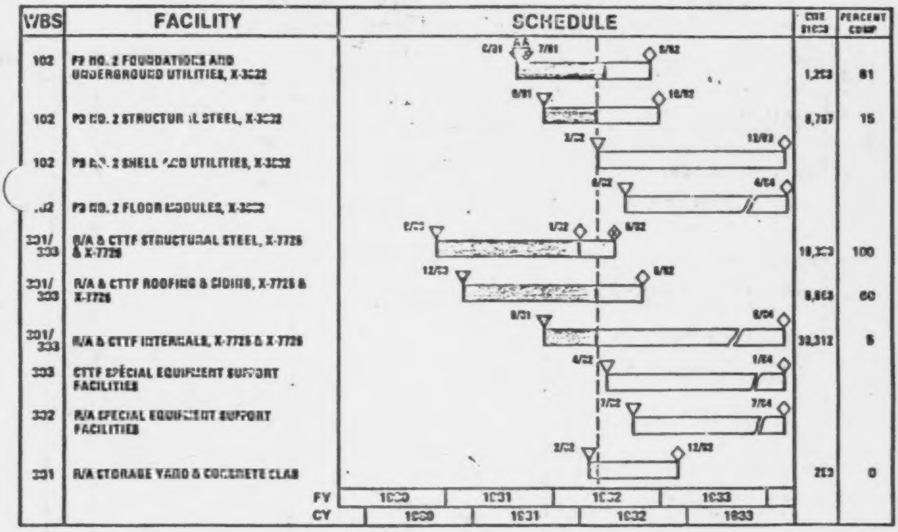
## GAS CENTRIFUGE ENRICHMENT PLANT

### CONSTRUCTION SUMMARY SCHEDULE



Question 17.s. - continued

## GAS CENTRIFUGE ENRICHMENT PLANT
### CONSTRUCTION SUMMARY SCHEDULE (CON'T.)

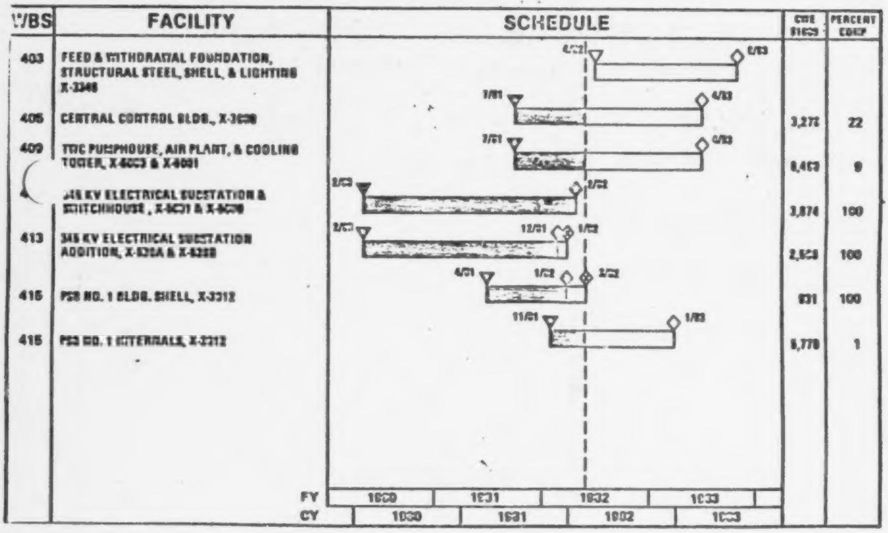


| WBS | FACILITY | SCHEDULE | CTE $1000 | PERCENT COMP |
|---|---|---|---|---|
| 102 | PB NO. 2 FOUNDATIONS AND UNDERGROUND UTILITIES, X-3002 | 6/81 7/81 8/82 | 1,263 | 81 |
| 102 | PB NO. 2 STRUCTURAL STEEL, X-3002 | 9/81 10/82 | 8,787 | 15 |
| 102 | PB NO. 2 SHELL AND UTILITIES, X-3002 | 3/82 12/83 | | |
| .02 | PB NO. 2 FLOOR MODULES, X-3002 | 8/82 4/84 | | |
| 301/ 303 | R/A & CTTF STRUCTURAL STEEL, X-7725 & X-7726 | 8/80 1/82 4/82 | 18,303 | 100 |
| 301/ 303 | R/A & CTTF ROOFING & SIDING, X-7725 & X-7726 | 12/80 8/82 | 8,863 | 60 |
| 301/ 303 | R/A & CTTF INTERNALS, X-7725 & X-7726 | 9/81 8/84 | 30,312 | 5 |
| 303 | CTTF SPECIAL EQUIPMENT SUPPORT FACILITIES | 4/82 1/84 | | |
| 302 | R/A SPECIAL EQUIPMENT SUPPORT FACILITIES | 7/82 7/84 | | |
| 301 | R/A STORAGE YARD & CONCRETE SLAB | 2/82 12/82 | 263 | 0 |

Question 17.s. - continued

## GAS CENTRIFUGE ENRICHMENT PLANT

### CONSTRUCTION SUMMARY SCHEDULE (CON'T.)

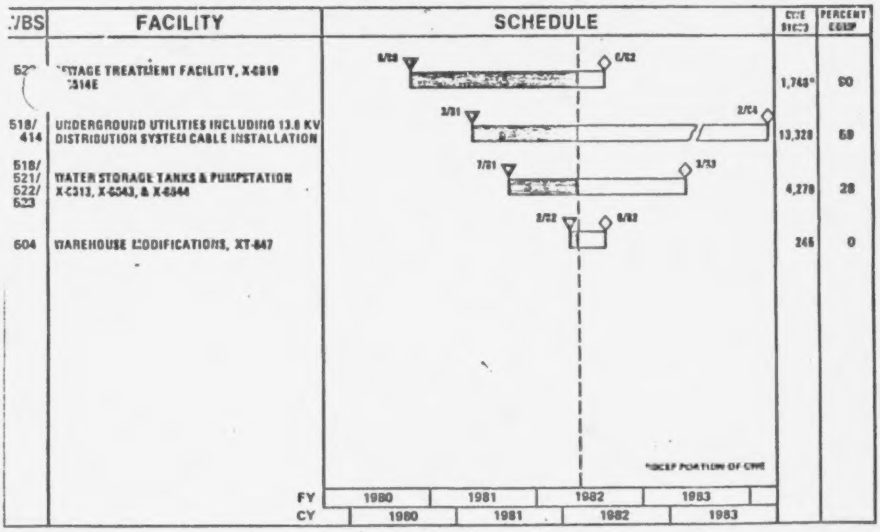


| WBS | FACILITY | SCHEDULE | CWE $1000 | PERCENT COMP |
|---|---|---|---|---|
| 403 | FEED & WITHDRAWAL FOUNDATION, STRUCTURAL STEEL, SHELL, & LIGHTING X-3346 | 4/82 – 8/83 | | |
| 405 | CENTRAL CONTROL BLDG., X-3020 | 7/81 – 4/83 | 3,272 | 22 |
| 409 | TRC PUMPHOUSE, AIR PLANT, & COOLING TOWER, X-6003 & X-6001 | 7/81 – 6/83 | 8,463 | 9 |
| 4 | 345 KV ELECTRICAL SUBSTATION & SWITCHHOUSE, X-5001 & X-5020 | 2/80 – 2/82 | 3,874 | 100 |
| 413 | 345 KV ELECTRICAL SUBSTATION ADDITION, X-530A & X-520B | 2/80 – 12/81 – 1/82 | 2,523 | 100 |
| 415 | PSB NO. 1 BLDG. SHELL, X-3312 | 4/81 – 1/82 – 2/82 | 831 | 100 |
| 415 | PSB NO. 1 INTERNALS, X-3312 | 11/81 – 1/83 | 5,778 | 1 |

Question 17.s. - continued

## GAS CENTRIFUGE ENRICHMENT PLANT

### CONSTRUCTION SUMMARY SCHEDULE (CON'T.)

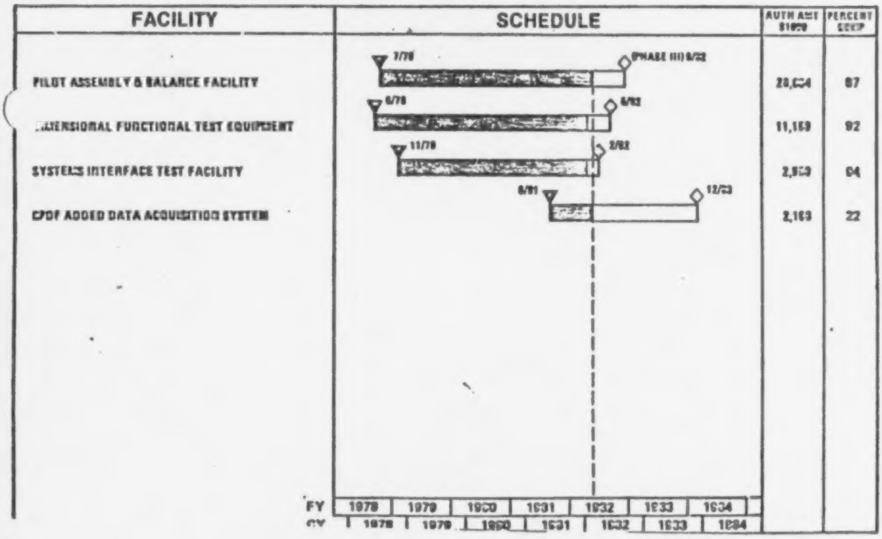


| [illegible]BS | FACILITY | SCHEDULE | CWE $(K) | PERCENT COMP |
|---|---|---|---|---|
| 52[illegible] | [illegible]AGE TREATMENT FACILITY, X-6619<br>[illegible]314E | 8/80 – 6/82 | 1,748* | 60 |
| 518/<br>414 | UNDERGROUND UTILITIES INCLUDING 13.8 KV DISTRIBUTION SYSTEM CABLE INSTALLATION | 3/81 – 2/84 | 13,328 | 60 |
| 518/<br>521/<br>522/<br>623 | WATER STORAGE TANKS & PUMPSTATION X-6313, X-6343, & X-6344 | 7/81 – 3/83 | 4,278 | 28 |
| 604 | WAREHOUSE MODIFICATIONS, XT-847 | 2/82 – 6/82 | 246 | 0 |

*GCEP PORTION OF CWE

Question 17.s. - continued

## GAS CENTRIFUGE ENRICHMENT PLANT
### OFF-SITE TECHNICAL SUPPORT FACILITIES (WBS 708)
### SUMMARY SCHEDULE



| | |
|---|---|
| Question 18. | Assume a decision was made today to limit the scope of GCEP to two process buildings, rather than eight process buildings as planned. How much of the FY 1983 request of $613,000,000 be reduced? In other words, how much is included in the GCEP request for all activities beyond the first two process buildings? |
| Answer 18. | If the decision were made to build only two process buildings, the FY 1983 request would not be reduced. The GCEP activities specifically related to process buildings 3 thru 8 would be in the FY 1985 budget and later. |

Question 19. Evaluate the impact on GCEP of FY 1983 budget levels $25 million, $50 million, $75 million and $100 million below the $613,000,000 request. In other words, evaluate the impact on GCEP of FY 1983 budget levels of $588 million, $563 million, $538 million and $513 million.

Answer 19: The reductions of $25 million, $50 million, $75 million and $100 million below the $613 million request would have the impact as follows:

| Obligation Level | Cost Impact on the TEC (In 83 dollars) | Schedule Impact |
|---|---|---|
| $588 Million | $ 0 - $ 10M | Delay from 0 to 6 months in completion of First Train and Bldgs 1 and 2. |
| 563 Million | 85 - 150M | Delay from 6 to 9 months in completion of First Train and Bldgs 1 and 2. |
| 538 Million | 175 - 250M | Delay from 9 to 12 months in completion of First Train and Bldgs 1 and 2. |
| 513 Million | 285 - 350M | Delay from 12 to 15 months in completion of First Train and Bldgs 1 and 2. |

With the reduction of $100 million in budget authority there may be a loss of one or more commercial suppliers of essential equipment or materials necessitating extensive government investment in manufacturing facilities now being supplied by the private sector. If we are not successful in establishing a satisfactory basis for continued private sector investment in manufacturing facilities required to provide these materials and equipment for GCEP, then Government facilities at a cost of $400-800M (83 dollars) will have to be established to satisfy the requirements.

Any delay in the project will increase total project cost due to escalation and the need to maintain major contractors for an extended period. Delays also impact the DOE's competive position because of the delayed economic benefits.

Question 20. What is the fully-escalated cost of a two-process-building GCEP, a three-process-building GCEP, a four-process-building GCEP, a five-process-building GCEP, a six-process-building GCEP, a seven-process-building GCEP, and an eight-process-building GCEP? What is the cost of each of these cases in FY 1983 dollars?

Answer 20. Fully escalated cost of GCEP is as follows:

| | | |
|---|---|---|
| 2 Buildings | - | $ 4,200M |
| 3 Buildings | | 5,205M |
| 4 Buildings | | 6,166M |
| 5 Buildings | | 7,177M |
| 6 Buildings | | 8,132M |
| 7 Buildings | | 9,137M |
| 8 Buildings | | 10,100M |

In FY 1983 dollars cost of GCEP is as follows:

| | | |
|---|---|---|
| 2 Buildings | - | $ 3,700M |
| 3 Buildings | | 4,255M |
| 4 Buildings | | 4,785M |
| 5 Buildings | | 5,340M |
| 6 Buildings | | 5,870M |
| 7 Buidlings | | 6,425M |
| 8 Buildings | | 6,950M |

Question 21. Provide data comparing projected SWU production costs from the 2.2 million SWU increment of GCEP with the SWU costs from the gaseous diffusion plants.

Answer 21.

| | Two Building GCEP Unit Costs $/SWU | Comparable GDP Unit Costs $/SWU |
|---|---|---|
| FY 1983 dollars .............. | 114 | 108 |
| FY 1996 dollars (9% escalation) | 205 | 330 |
| Above + 3% higher power escalation .................. | 209 | 469 |

The two building GCEP unit costs in constant FY 1983 dollars are slightly higher than comparable unit costs from the diffusion plants. However, in escalated (at 9%) dollars the GCEP unit costs are less than comparable diffusion costs when GCEP is completed and full production begins. If power costs are escalating at higher rates than general inflation, (for example 3%) the GCEP unit costs are even more favorably compared to diffusion costs.

| | Eight Building GCEP Unit Costs $/SWU | Comparable GDP Unit Costs $/SWU |
|---|---|---|
| FY 1983 dollars .............. | 64 | 88 |
| FY 1996 dollars (9% escalation) | 130 | 270 |
| Above + 3% higher power escalation .................. | 133 | 384 |

The GCEP has been designed to produce with eight process buildings and at full production. The GCEP unit cost is considerably less than comparable unit costs from the diffusion plants.

Question 22. Provide documentation supporting DOE's case for an appropriate GCEP introduction strategy given continued reductions in nuclear capacity growth projections and the possibility of a viable advanced isotope separation enrichment technology being demonstrated by the end of the decade and operationally available by the mid-1990's.

Answer 22. The answers to these questions are contained in the December 1981 uranium enrichment operating plan provided in answer to question 11.

Question 23. Provide a detailed description of the AIS process selection methodology.

Answer 23. Attached is the Advanced Isotope Separation Program selection criteria which contains the information requested.

# ADVANCED ISOTOPE SEPARATION PROGRAM SELECTION CRITERIA

## 1.0 Purpose and Summary

The purpose of this document is to set forth the selection criteria and grading system to be used in selecting one of the Advanced Isotope Separation (AIS) processes for engineering development by mid FY82. Selection will be based on in-depth reviews and evaluations of each of the three contending processes and the prime contractors listed below:

Atomic Vapor Laser Isotope Separation (AVLIS) being pursued by Lawrence Livermore National Laboratory (LLNL),

Molecular Laser Isotope Separation (MLIS) being pursued by Los Alamos National Laboratory (LANL),

Plasma Separation Process (PSP) being pursued by TRW, Inc.

The selection process will primarily involve interactions among the participating process developers, and a Process Evaluation Board (PEB).

The function of the PEB is to recommend to the Under Secretary, the DOE selecting official, which process should proceed toward full scale engineering development.

## 1.1 AIS Purpose and Objectives

### 1.1.1 AIS Goals and Benefits

The goal of the DOE uranium enrichment program is to meet domestic, foreign, and U.S. Government requirements for uranium enrichment services in the most economical, reliable, safe and environmentally acceptable manner possible. The process which best meets the above objectives will be selected.

The goal of the AIS program for the last several years has been to develop a uranium enrichment technology which will produce enriched uranium at a cost less than $40/SWU (computed at 10 percent interest and 10 year write off). Recent changes in economic assumption of extending the write off time from 10 years to 25 years has the affect of lowering the $40/SWU to about $30/SWU. Benefits of the lower enrichment cost support the following missions:

- Replace power intensive diffusion plants
- Economically lower the tails assay of the enrichment enterprise
- Supply additional separative work capacity as required for expansion of nuclear power.

The relative value of these missions measured in terms of the anticipated present value benefit is presented in Table 1.1 for a medium nuclear power deployment projection.

Table 1.1

AIS Present Value* Benefits for a $30/SWU Process

(Through the Year 2024)

(FY 1980 Dollars** in Billions)

| MISSION | |
|---|---|
| Replace Diffusion Plants | 2.7 |
| Lower Tails Assay | 2.0 |
| New Capacity | 0 |
| Total | 4.7 |

*Discount Rate = 10%/yr
**LEVEL OF NUCLEAR POWER SUPPORTED BY THE U.S. ENRICHMENT ENTERPRISE IN THE YEAR 2000 IS (250 GWe)

### 1.1.2 AIS Program Objectives

The next significant engineering scale up is the development module (DM). The DM and other offline development in the late 1980's have the following goals and objectives:

- First fully integrated process demonstration
- Mechanism for technology transfer
- Development of firm data base to project plant economics
- Readiness of process to proceed to production with low to moderate technical risk

Program plans submitted for consideration in the selection process should outline the tasks and estimate the costs of the engineering development and demonstration of the required technology to the start-up of a nominal 9 million SWU/yr plant in the early to mid 1990's.

### 1.2 Selection Schedule and Information Flow Sequence

The schedule for making the selection is presented in Table 1.2. The process will culminate in early April 1982 when the PEB and Assistant Secretary of Nuclear Energy recommend to the Under Secretary which process to select for engineering development. The PEB will be active in the selection process although no schedule of their activities is presented. It is expected that the PEB will:

- Visit all sites and facilities.
- Obtain independent evaluations of data and designs as required.
- Rank the three contending AIS processes based on the selection criteria.

## Table 1.2

## SELECTION INFORMATION FLOW SEQUENCE

| Action Item or Transmittal | From | To | Date |
|---|---|---|---|
| 1. Revised Baseline/Alternates Description | Labs | UCC-ND/PEB | 09/01/81 |
| 2. Final Conceptual Design Report on Development Module | Labs/UCC-ND | DOE | 09/15/81 |
| 3. Projections of Preprototype Performance | Labs | PEB | 09/30/81 |
| 4. Document Preprototype Capabilities Relative to Scaling and Future Systems | Labs | PEB | 11/01/81 |
| 5. Documentation of Science and Technology Base | Labs/UCC-ND | PEB | 12/01/81 |
| 6. Economic Assessment Draft | UCC-ND | Labs/PEB | 12/10/81 |
| 7. Complete Peer Review Documents | Labs/UCC-ND | PEB | 12/15/81 |
| 8. Complete Program Plan, Costs, and Schedule | Labs/UCC-ND | PEB | 01/07/82 |
| 9. Recommended Changes in Baseline Plant Design (Limited to changes where process model and cost equations remain valid) | Labs | UCC-ND/PEB | 01/08/82 |
| 10 Preconceptual Design Report for Large Plant Study | Labs/UCC-ND | PEB | 01/10/82 |
| 11. Proliferation Assessment |  | PEB | 01/31/82 |
| 12. Safeguards Assessment (Draft) | BNL | PEB/Labs/UCC-ND | 01/31/82 |
| 13. Updated Science, Technology and Preprototype Information | Labs/UCC-ND | PEB | 02/01/82 |
| 14. Final Economic Assessment | UCC-ND | PEB/Labs | 02/12/82 |
| 15. NEPA Environmental Assessment (Draft) | PNL | PEB/Labs/UCC-ND | 02/15/82 |
| 16. Final Documentation of Preprotype Performance | Labs | PEB | 03/01/82 |
| 17. Final Presentations to PEB | Labs/UCC-ND | PEB | 03/16 - 19/82 |
| 18. PEB Recommendation | PEB | AS/US | 04/02/82 |

## Table 1.2 (continued)

## SELECTION INFORMATION FLOW SEQUENCE

US - Under Secretary
UCC-ND - Union Carbide Corporation-Nuclear Division
LANL - Los Alamos National Laboratory
Labs LLNL - Lawrence Livermore National Lab
TRW
PNL - Pacific Northwest Laboratory

AS - Assistant Secretary
PEB - Process Evaluation Board
DOE - Advanced Isotope Separation Office
BNL - Brookhaven National Laboratory

## 1.3 Overview of Selection Criteria

A point system will be used to rank the processes with the evaluation broken down into several categories as illustrated in Table 1.3.

The objectives of the technical aspects of the evaluation of each process are to ascertain its current status, to project its potential, and to evaluate the risk associated with the projection to future potential. The great technical variety between the programs requires the development of a general methodology for evaluation which will allow for the application of identical rules to all aspects of each process. In order to measure the relative importance of the various aspects of each process, where practicable a measure of system or subsystem performance and costs must be related to their impact on some common measure of benefit such as $/SWU.

Selection criteria for environmental assessments, proliferation and safeguards will be used at the PEB's discretion. Based on previous assessments, it is not anticipated that these factors will be the decisive ones; however, they will be evaluated.

TABLE 1.3

EVALUATION CATEGORIES AND POINT ALLOCATIONS

| CATEGORY | POINTS | TOTAL FOR SECTION |
|---|---|---|
| DESIGN EVALUATIONS | | 15 |
| A. BASELINE PLANT DESIGN | | |
| B. DEVELOPMENT MODULE DESIGN | | |
| PROCESS PERFORMANCE AND RISK EVALUATIONS | | 60 |
| A. SYSTEMS INTEGRATION, STATUS, AND SCALING | | |
| 1. PREPROTOTYPE PERFORMANCE | | |
| 2. INTEGRATED EXPERIMENTS | | |
| B. SUBSYSTEM STATUS AND SCALING | | |
| 1. FEED SOURCE | | |
| 2. INTERACTION ZONE AND PROCESS CHAMBER | | |
| 3. ELECTROMAGNETIC SIGNALS | | |
| 4. EXTRACTOR/COLLECTOR | | |
| 5. INTERSTAGE EQUIPMENT | | |
| C. SYSTEM INTEGRATION ANALYSIS | | |
| ECONOMIC EVALUATION OF BASELINE PLANT | | 10 |
| A. BENEFIT FROM SWU COST, DEVELOPMENT COST AND PROCESS DEPLOYMENT DATE | | |
| TECHNOLOGY DEVELOPMENT AND PRODUCTION IMPLEMENTATION PLAN | | 15 |
| | TOTAL POINTS | 100 |

## 2.0 Design Evaluation

A prerequisite for engineering development of any process is the existence of well conceived and complete designs for both demonstration facilities and a full scale plant. The objectives of the design activities include establishing a consistent, comprehensive framework for cost estimates, schedules, operational evaluations, and various assessments, as well as providing a reference point for process/program requirements and the associated technical evaluations. Such designs also help the developer to focus on those issues most relevant to the economic feasibility of a given process. Keeping in mind the above guidelines it is the purpose of this section to provide a scoring system for evaluating the completness and depth of both the baseline plant and DM designs.

The evaluation of the designs to be accomplished in this section will serve as a measure of risk based on the completeness of the designs. The evaluation will give visibility to the scaling issues for each process and, since a considerable amount of engineering has been accomplished on these designs, will also be indicative of the level of technological sophistication required for each process.

## 2.1 Baseline Plant Design

Each process proponent in conjuction with UCC-ND is responsible for developing the design of a baseline isotope separation plant which employs his technology. The information presented in subsequent sections on Development Module Design, Preprototype Performance, Process Subsystem Status and Process Economics should directly support and lead to the Baseline Plant Design. The Baseline Plant Design serves as a reference for measurement of the risk inherent in projecting the current state of knowledge to full plant conditions. The plant design for each process is based on primary enrichment deployment of each technology. The minimum plant requirements to be satisfied by the design are listed in Table 2.1.

Table 2.1

MINIMUM BASELINE SEPARATION PLANT
REQUIREMENTS

| ITEM | REQUIRED PLANT VALUE |
|---|---|
| Separation Capacity | Nominal 9 million SWU/yr. |
| Product Assay | 3.2% $^{235}U$ or greater |
| Tails Assay | .08 to .12 $^{235}U$ |
| Feed Assay | 0.711% $^{235}U$ |
| SWU Cost* | Less than $30/SWU |

*This minimum SWU cost is to include any difference in the cost associated with the preparation of the metal feed stock for AVLIS or PSP.

The assessment of the plant design will be based on the point system shown in Table 2.3. The overall plant design has been broken into six subsystems which are assigned starting points weighted on the basis of their effect on unit cost of separative work at the baseline.

Definitions of the subsystem are presented in Table 2.2.

It is recognized that the plant design, being a paper study, represents how the technology might evolve based on the information available today. Therefore, excessive detail on the baseline plant design is not warranted. However, since the baseline plant will serve as the reference point for the risk analysis, it is important that the plant concept be defined in sufficient detail to establish a credible capital cost estimate and to evaluate the design as an integral system including the aspects of operability, reliability, and maintainability.

To determine the quality of the design effort each subsystem will be evaluated from the following points of view:

o Components Definition
Are all components defined in sufficient detail to identify requirements such as heat removal, floor space, utility requirements, etc.?

o Equipment Integration
Are interface requirements of components specified?

o Operational Requirements
Was plant designed with operability as an integral part of design or was it included as an after thought?

o Maintainability
Was plant designed with maintenance as a integral part of the design? Are facilities included in the design to rework equipment? Is the layout consistant with the assumed failure rate?

## TABLE 2.2

## DEFINITION OF SUBSYSTEMS

FEED SOURCE

The direct source of process feed plus any auxiliary power supplies and equipment necessary to put the feed in the proper state required by the separation process and any equipment and maintenance necessary to maintain the feed rate at the desired level.

INTERACTION REGION AND PROCESS CHAMBER

The immediate structure necessary to house the process, equipment necessary to perform effective separation. This definition includes all maintenance equipment and facilities required for operation of the process chamber as well as all process physics.

ELECTROMAGNETIC SIGNALS

For the laser based processes this shall mean all oscillators, amplifiers, power supplies, multiplexers, beam conditioning, transport and steering optics necessary to generate the proper pulse rates and fluences at the point where the beams enter the process chamber. For the PSP process the term electromagnetic signals means the RF generator and excitation coil assembly. All maintenance equipment and facilities necessary to keep the electromagnetic signals on line are included in this definition.

TABLE 2.2 (Continued)

DEFINITION OF SUBSYSTEMS

EXTRACTOR/COLLECTOR

All equipment and process physics necessary to collect product and tails material. This is meant to include all equipment necessary for the collection and treatment of side streams and maintenance equipment and facilities for refurbishing collector parts.

INTERSTAGE EQUIPMENT

All equipment necessary for process stream cleanup, refluorination, recompression, casting, and transport between process stages and all maintenance equipment required.

BALANCE OF PLANT

The term defines all elements of plant and maintenance facilities not included in the previous categories. Balance of plant shall include the process buildings, cooling water requirements,electrical switchyard, transformation, distribution systems, gas liquifaction plants, all chemical conversion facilities, recycle stream processing systems, and disposal systems for waste streams as required for a process. Also all control and data acquisition elements for the plant and all control and data acquisition elements for specific subsystems.

The plant subsystems listed in Table 2.2 are to be graded according to the quality of the design and criteria listed in Table 2.3.

The Systems Importance Weighting Factor, as identified in Table 2.3, will be determined by January 30, 1982 upon issue of the large plant studies. As an example, the score for the feed source would be calculated in the following manner:

$$\text{SCORE FOR FEED SOURCE} = X_1[Y_1{*}QF_{\text{COMPONENT DEFINITION}} + Y_2{*}QF_{\text{INTEGRATION}} + Y_3{*}QF_{\text{OPERATIONS}} + Y_4{*}QF_{\text{MAINTENANCE}} \quad Y_5{*}QF_{\text{SAFETY}}]$$

TABLE 2.3

BASELINE PLANT DESIGN EVALUATION SHEET

PROCESS ____________________

| | | FEED SOURCE | INTERACTION REGION AND PROCESS CHAMBER | ELECTROMAGNETIC SIGNALS | COLLECTOR | INTERSTAGE EQUIPMENT | BALANCE OF PLANT |
|---|---|---|---|---|---|---|---|
| System Importance Weighting Factor | | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
| EVALUATION CRITERIA | EVALUATION CRITERIA IMPORTANCE | | | | | | |
| 1. Component definition and requirements | $Y_1$ | | | | | | |
| 2. Level of design details and integration | $Y_2$ | | | | | | |
| 3. Operational requirements and characterization | $Y_3$ | | | | | | |
| 4. Maintenance plan and facility definition | $Y_4$ | | | | | | |
| 5. Safety analysis | $Y_5$ | | | | | | |
| Point Sum | | | | | | | |

| Maximum Score | Awarded Score |
|---|---|

TOTAL POINTS ____________

TOTAL POINTS DIVIDED BY
EQUALS FINAL SCORE ____________

Quality Factor for Baseline Plant Design

| Design Quality Factor % | Superior | Adequate | Marginal | Inadequate |
|---|---|---|---|---|
| | 75-100 | 50-75 | 25-50 | 0-25 |

## 2.2 Development Module Design

In the course of the AIS program, each process proponent working closely with UCC/ND has been responsible for designing a process "development module." These development modules will be the first significant scale up of the respective technologies wherein all process science and integration issues are active.

Each proponent working with UCC/ND is responsible for submitting a document which describes the development module design. The evaluation of this design will closely parallel the evaluation of the Baseline Plant design except the emphasis will be placed on specific process active subsystems and the role of the DM. The elements to be evaluated for each development module design are listed in Table 2.4.

The same definitions that were presented in Table 2.2 apply to the subsystems listed in Table 2.4. The subsystems listed in Table 2.4 are to be evaluated according to the system importance weighting points, evaluation criteria importance, and quality of the design as specified in the table. The method of assigning a score for each criteria and each subsystem proceeds exactly as described for the Baseline Plant design.

TABLE 2.4

DEVELOPMENT MODULE EVALUATION SHEET

PROCESS ____________________

| | | FEED SOURCE | INTERACTION REGION AND PROCESS CHAMBER | ELECTROMAGNETIC SIGNALS | EXTRACTOR/ COLLECTOR | INTERSTAGE EQUIPMENT |
|---|---|---|---|---|---|---|
| System Importance Weighting Factor | | | | | | |
| EVALUATION CRITERIA | EVALUATION CRITERIA IMPORTANCE | | | | | |
| 1. Component definition and requirements | $Y_1$ | | | | | |
| 2. Level of design details and integration | $Y_2$ | | | | | |
| 3. Operational requirements and characterization | $Y_3$ | | | | | |
| 4. As a step to production plant | $Y_4$ | | | | | |
| Point Sum | | | | | | |

Maximum Score / Awarded Score

TOTAL POINTS DIVIDED BY

EQUALS FINAL SCORE ____________

Quality Factor for Demonstration Module Design

| Design Level | Superior | Adequate | Marginal | Inadequate |
|---|---|---|---|---|
| Quality Factor % | 75-100 | 50-75 | 25-50 | 0-25 |

## 3.0 Process Performance and Risk Evaluation

The intent of this section is to permit the PEB to arrive at a full understanding of the status of each process relative to the requirements for a nominal 9 million SWU/yr plant. Evaluation scores should reflect the degree of risk involved in scaling a process from what has been experimentally demonstrated to a full scale enrichment plant.

## 3.1 Preprototype Performance and Integration Experiments

This subsection will focus on the highest levels of process integration that have been achieved for the three contending AIS processes. If a given process has achieved a fully integrated demonstration in a subscale facility and the equipment is truly a scaled-down version of plant components and the measured parameters have the values that are required for the baseline plant, that process should receive a higher score than a process whose performance is derived from a combination of isolated experiments. If the measured parameters are less than those required for the baseline plant, then the ratio of these values to those for the baseline plant will provide an indication of the remaining scaling required for process implementation. However, the ratio is not necessarily a good measure of the difficulty of the development task. Each case must be evaluated independently. Parameters which define physical size should be compared to the plant parameters for the largest replicable separation module or separation stage. This subsection is divided into two levels of system integration. The first is referred to as "preprototype performance" and the second is referred to as "integration experiments." A process preprototype is a subscale system wherein the feed source, interaction zone and process chamber, electromagnetic signals, enriched product collector, and tails collector operate simultaneously. The process physics of all subsystems in a preprototype should be the same as the process physics for a process module or a stage of a baseline plant. A successful preprototype demonstration by a process proponent will reduce the risk of projecting to full plant performance.

The integration experiments represent the highest levels of system integration that have been achieved in laboratory scale experiments or partial integration experiments. The experimental equipment need not be subscale plant components nor do all subsystems have to be present. The experimental data should, however, address some integration issue such as subsystem scaling effects on integration which are not treated as completely in the preprototype experiment. For an integration experiment, the closer the subsystems are to faithfully reproducing plant physics and design concepts, the more credible will be an extrapolation of the performance to full scale.

### 3.1.1 Preprototype Performance

Each process proponent is responsible for submitting a document which describes their preprototype design, operation characteristics, measured measured performance, and scale relative to equipment in a full scale plant. The evaluation in this section will be based on the contribution of the preprototype to reduction of risk in scaling to baseline plant conditions. The scoring will include an evaluation of the degree to which the preprototype subsystems represent subscale plant units and the performance of the preprototype relative to the largest module or stage in a full scale plant. Considerations which are important in evaluating the preprototype systems are summarized below:

1. The level of subsystems integration that has been achieved. Are the basic separation elements of a plant module or stage present?

2. Degree to which the preprototype subsystems represent plant module or stage equipment. Are there subsystem substitutions or modifications that are not representative of plant equipment?

3. The degree to which the physics of the preprototype system will duplicate the physics in a module or stage in a full scale plant. Are all pertinent physics active in the preprototype or are issues neglected or altered by equipment substitution?

4. Is the level of performance of the preprototype at or below predicted or expected values?

5. Is the scale of the preprototype significant relative to what is required for a module or stage in a full scale plant?

For items 4 and 5, Table 3.1 presents a list of suggested performance parameters which the PEB may use to judge the performance of a given preprototype.

### TABLE 3.1

### SUGGESTED PERFORMANCE PARAMETERS FOR EVALUATING PREPROTOTYPE PERFORMANCE

| | PREPROTOTYPE SYSTEM | | |
|---|---|---|---|
| PERFORMANCE PARAMETER | EXPERIMENTAL VALUE | DESIGN VALUE | PLANT VALUE |
| Uranium throughput | | | |
| Separative capacity | | | |
| Process interaction zone size | | | |
| Enrichment Parameters | | | |
| Process cut | | | |
| Run time | | | |

Based on the above considerations the PEB is to arrive at an evaluation of the reduction in scaling risk supported by the level of integration and performance of a specific preprototype. Table 3.2 is a listing of the specific risk reduction levels to be used with an assigned percentage range for awarding a score.

TABLE 3.2

RISK REDUCTION OF INTEGRATION AND SCALING TO

THE BASELINE PLANT BASED ON PREPROTOTYPE EXPERIMENT

| RISK REDUCTION | POINT PERCENTAGE RANGE (%) |
|---|---|
| HIGH | 75-100 |
| MEDIUM | 50-75 |
| LOW | 25-50 |
| VERY LOW | 0-25 |

### 3.1.2 Integration Experiments

Each process proponent is responsible for forwarding documentation which describes integration experiments for his process. Such documentation should describe the experimental equipment and how it relates to plant scale equipment both in performance and design. Scaling issues should clearly be identified and the performance of the integration experiment should be documented to an extent that will permit comparison to the performance predicted for a full scale plant.

The considerations that are important in evaluating the integration experiments are:

1. The level of subsystem integration that has been achieved. Are the basic four elements of the separation process present (feed source, interaction zone and process chamber, electromagnetic signals, product collection)?
2. Is the scale of the equipment and measurements made conducive to extrapolation to baseline plant design conditions?
3. To what extent does the physics of the integration experiment duplicate the physics in a plant scale module or stage?
4. Are the measured values of the performance parameters characteristic of plant scale equipment?

## 3.2 Subsystem Status and Scaling

### 3.2.1 Data Requirements

The purpose of this section is to set forth a methodology the PEB can use to evaluate the risk of integrating components into subsystems and scaling major process subsystems to the size and performance of plant scale equipment. For this section each process proponent must provide information on each subsystem which:*

1. Defines the performance and design requirements of the baseline plant design for that subsystem.
2. Presents the experimental data base for that subsystem.
3. Shows to what extent the experimental data agrees with theory.
4. Presents an extrapolation of the current level of knowledge for that subsystem to plant scale conditions which includes the most optimistic, most pessimistic and expected values.
5. Presents the costs of the subsystem for the baseline plant design case and explains how they are derived.
6. Presents the integration issues to be addressed in combining the components of the subsystem and details how the integration will be achieved.

The evaluation of risk to be made by the PEB is taken relative to the baseline plant design.

The goal of a process proponent in this section should be to demonstrate that the data base clearly supports the contention that the process is ready for advancement to an engineering development phase, and that the scaling to a baseline plant is reasonable.

Proponents should discuss the risk associated with component integration for any subsystems not demonstrated at full scale in an integrated manner and should discuss any experience with subscale or analogous equipment which would reduce risk. Each proponent should discuss the significant operational aspects of full plant operation and justify availability assumptions. Data should also be submitted to validate various costing models including justification of learning curves and quantity discounts.

---

*It is realized that the large plant preconceptual design studies are a joint effort between the process proponent and UCC-ND engineering and that UCC-ND had the responsibility for issuing the preconceptual design study. It is also recognized that there may be disagreements on large leverage items for capital cost. Item 5 is to include these potential disagreements and the preconceptual design.

For operating costs, data should be presented on replacement and refurbishment cost including both equipment and labor. Experience based on existing maintenance facilities, time and motion studies, or operating costs on analogous equipment can be submitted.

In order to go from the current demonstrated performance to the anticipated plant performance each process must scale numerous subsystems in terms of parameters such as production costs, performance, degree of integration, operating environment, or lifetime. The proponent must explain and justify each of these required subsystem scalings. The scaling must be justified to at least the baseline plant requirements, but further projections may also be presented. The accuracy of the techniques should be discussed and potential errors estimated.

The major subsystems to be considered are:

Feed Source
Interaction Zone and Process Chamber
Electromagnetic Signals
Extractor/Collector
Interstage Equipment
Balance of Plant

The minimum data required for each of the three contending processes is listed in Appendix A. In all cases of data presentation, whether tabular or graphical, the baseline plant design value is to be included as a reference point along with the DM and offline development in the DM time frame. In all cases, experimental data will be accompanied by error bars to indicate the experimental accuracy of the measurement and where applicable the predictions from the process model or appropriate submodel will be included on the same graph.

### 3.2.2 Subsystem Risk Evaluation and Scoring

Based on all of the information presented in the previous section the PEB is to arrive at an evaluation of the risk involved in projecting to a baseline plant design.

The maximum points associated with each subsection will be based upon the influence of process performance and cost parameters of the subsystem upon the cost of separative work for the overall system. A weighting method utilizing the UCC-ND economic codes and the multivariable sensitivity analysis will be developed and approved by the PEB. It will be the responsibility of the PEB to specify the values of the minimum, mode and maximum parameters values used in calculating the overall performance distribution functions, from which the subsystem sensitivities are derived and the maximum points in Table 3.3 are established.

TABLE 3.3

Maximum Points* for Major Subsystems

| SUBSYSTEM | PROCESS | | |
|---|---|---|---|
| | AVLIS | MLIS | PSP |
| Feed Source | | | |
| Interaction Zone and Process Chamber | | | |
| Electromagnetic Signals | | | |
| Extractor/Collector | | | |
| Interstage Equipment | | | |
| Balance of Plant | | | |

*Preliminary TBD - Final values will be determined by January 29, 1982, upon completion of large plant studies.

The points shown for each major subsystem are to be awarded based on the overall confidence the PEB assigns to the subsystem.

Table 3.4 lists confidence conditions ranges for various levels of status and Table 3.5 lists confidence conditions for major cost drives. The relative importance of cost and performance varies between subsystems, therefore the relative importance of the two confidence factors in determining the overall confidence factor is left to the judgement of the PEB.

## TABLE 3.4

## Confidence Factors for Evaluating the Risk of Major Subsystem Scaling to Baseline Plant Conditions

CONDITION

1. Full size subsystem operating in a plant environment. No scaling required.
2. Subscale subsystem operation at plant design values of most parameters. Integration and scaling to larger sizes is straightforward.
3. Subscale subsystem operation at conditions off design from a plant. Achieving full plant design conditions requires further but limited development.
4. Subscale subsystem operating at conditions off design from a plant. Achieving full plant design conditions requires significant further development.
5. Components of subsystem operating in isolated tests. Integration not demonstrated but is straightforward. Scaling laws tested.
6. Components of subsystem operating in isolated tests. Integration not demonstrated and offers significant problems. Scaling not straightforward.
7. Physics of subsystem components demonstrated. Subsystem designed.
8. Physics of subsystem based on extrapolation from similar applications at different conditions. Subsystem designed.
9. Subsystem concept based on theoretical extension of physics. No detailed designs or experiments.
10. Subsystem requirements established. No experiments. No detailed designs. New technology required.

## TABLE 3.5

## Confidence Factors for Evaluating the Risk of Major Subsystem Costs Exceeding Baseline Plant Values

CONDITION

1. Full scale equipment produced and delivered in quantity.
2. Full scale equipment delivered or commercially available for limited number. Bids received for quantity.
3. Full scale equipment delivered or commercially available for limited number. Cost estimated for quantity.
4. Subscale equipment delivered or commercially available for limited number. Bids received for quantity at full scale.
5. Subscale equipment delivered or commercially available for limited number. Cost estimated for quantity at full scale.
6. Similar equipment manufactured. Costs based on specifications.
7. Cost estimates based on designs.
8. Cost estimates based on general costing rules.

Table 3.6

Subsystem Evaluation Sheet

Process ____________________

| Subsystem | Performance Confidence Factor | Costing Data Confidence Factor | Subsystem Confidence Factor | Maximum Possible Points | Point Award |
|---|---|---|---|---|---|
| Feed Source | | | | | |
| Interaction Zone and Process Chamber | | | | | |
| Electromagnetic Signals | | | | | |
| Extractor/Collector | | | | | |
| Interstage Equipment | | | | | |
| Balance of Plant | | | | | |

Total Points = ________

The tables cannot cover all possible combinations of data available on various subsystems, but they do provide general guidance against which individual data packages can be judged. For lifetime estimates data taken for short periods should be treated as off design data and the scaling to expected lifetimes must be judged similar to any other performance parameters. Measurement of basic lifetime limiting mechanisms will be treated as off line experiments.

The total point score for subsystem and scaling will be arrived at by multiplying the overall confidence factor assigned to each subsystem by the points assigned to that subsystem in Table 3.3 and adding the points as indicated in Table 3.6.

## 3.3 System Integration Analysis

This section deals with estimating the risk and performance degradation associated with integrating all full scale subsystems into a full scale system.

Studies should be presented which show how major subsystems, as identified in Section 3.2, will be integrated in a plant environment and how both subsystem and system performance will be modified during integration. These studies should discuss how integration effects have been measured with current subscale subsystems and how effects scale to plant size. Effects which can not be measured in current size test beds should also be discussed. Estimates of plant availability should be presented and estimates should indicate how subsystem availability influences plant availability and performance.

A maximum of  points has been allocated for the degree to which system integration analysis reduces the risk of predicting and scaling to full plant conditions. Table 3.2 will be used to evaluate the level of risk reduction.

## 4.0 Economic Benefits Evaluation of Baseline Plant

### 4.1 Assumptions

Proper assessment of an AIS process requires some measurement of the future monetary benefits which justify expenditure of research and development funds. The correct measure must contain the element of time (the time value of money and the use of a proper figure of merit). For measurement of a figure of merit, the unit cost of separative work ($/SWU) has traditionally been used and has the advantage of usually being independent of the particular separation task defined. Since the ultimate end use of enrichment plant product is in fabricated nuclear reactor fuel, the unit cost of 3.2 percent U-235 product, with its feed, conversion and separative work components, is also a useful figure of merit, however, it has the disadvantage of being most heavily weighted by the cost of ore concentrate. In previous economic analysis the cost of preparing the uranium metal shapes required by atomic vapor AIS processes have not been included in the separative work cost since they are not an inherent part of the separation process (enrichment is traditionally treated as a "TOLL" process in which the same chemical form, $UF_6$, is received and shipped and only the cost of separation is charged to the customer). For AIS, however, only the MLIS process fits this approach. In order to fairly assess all three AIS processes, the AVLIS and PSP unit cost should include the additional capital facilities and/or operating cost required to convert the raw feed (uranium metal "derbies") to specified feed forms and the differential cost of preparing these uranium metal "derbies" from ore concentrate over that of preparing $UF_6$ from ore concentrate. In addition, any incremental costs in the conversion of $UF_6$ or U into $UO_2$ will be included.

A more detailed discussion of the economic assumptions, approved by the PEB is presented in Appendix B.

### 4.2 Calculation of Benefits

Benefits from the deployment of an AIS technology are not derived from figures of merit alone but rather they arise from differences in these figures of merit from those of competing or existing enrichment technologies. The Department of Energy is spending present dollars on an R&D program in the hope that an improved technology will cause fewer future dollars to be spent. The potential benefit to be obtained is calculated as the present value of these future expenditure differences. For this reason the year of AIS process deployment becomes an important factor. The pattern of future development and implementation funding will also have a major impact on process deployment. The figure of merit used to determine points for the economic benefit will be related to the net present value of projected savings offered by each technology.

The baseline plant considered in this section represents our best understood plant technology and an estimated cost, projected at the time a process would begin production. The chance that these goals may not be reached due to performance, scaling or cost uncertainty constitutes the risk associated with a process which is evaluated in the other sections.

The economics benefits of the AIS program have been previously summarized in Table 1.1. Factors which affect these benefits, within a fixed nuclear power projection are:

- Technology deployment date
- Deployment rate
- Cost of alternatives (Gaseous Diffusion and Advanced Gas Centrifuge)
- SWU cost of AIS technology
- Normal feed sale floor
- Future development cost

The optimum tails assay (assay resulting in the lowest cost for the sum of ore cost and SWU cost) for an enrichment complex is based on the cost of the last incremental SWU addition. Since this optimum is flat, other issues such as the ability to raise construction capital and restraints on the mining and milling industry will be used to determine the length of time required to reach the optimum tails assay. Table 4.1 presents the assumptions for the above independent variables.

Assuming a nuclear power projection of 250 GWe by the year 2000 and completion of the 8.8 million SWU Portsmouth Gas Centrifuge Plant the economic benefit of each AIS technology will be calculated through the year 2010 and discounted to FY 1982 using a 10 percent discount factor. Each program (LANL, LLNL, and TRW) participant should devise a strategic deployment plan which best fits their technology by showing how individual process modules or cascades are designed to accommodate the market place requirements. Specifically, how does each technology offer the flexibility of producing a range of product assays, accept different feed assays (normal, tails stockpile material, tails assay from GCEP, and tails assay from the gaseous diffusion plant as they are phased out). The deployment plan should meet the enriched product demand requirements in each year of the campaign.

The PEB will review each participants deployment plan (including participants suggested values for the minimum, mode, and maximum parameters for variables associated with table 4.1) and establish values of the minimum, mode, and maximum parameters associated with Table 4.1 and the minimum, mode, and maximum parameters used in defining the maximum points in Table 3.3. This information will then be given to UCC-ND to determine the relative probability of the net present value savings for the three technologies, using the Monte Carlo analysis.

## Table 4.1

## Major Assumptions for Calculating Net Present Value of Benefits

Technology Deployment Date

Each proponent documents and justifies the rationale for deployment date.

Deployment Rate

The deployment rate will be limited by the ability of private industry to deliver special equipment (proponent must justify) or to limit the obligation of construction funds to no more than $500 million (end of FY 1981 dollars) per year. The case resulting in the lower deployment rate will be used.

Cost of Alternatives

Replace Diffusion Plants

The out-of-pocket cost of operating gaseous diffusion plants will be limited to the system average power costs. (FY 1982 costs are expected to be ∽ $70/SWU at 32 mills/kwh). Unit power costs for the 1990's will be calculated assuming power costs escalate at an annual rate of 2% above the national inflation rate.

Advanced Gas Centrifuge

The cost of advanced gas centrifuge (SETIV) is assumed to be $71/SWU.

Cost of Uranium Ore

The cost of uranium ore is assumed to be $78/KgU ($30/pound yellow cake).

SWU Cost of AIS Technology

SWU cost will be estimated at the baseline design point.

Normal Feed Sale Floor

Section 161V of the Atomic Energy Act of 1954, as amended, provides that the Government shall "assure the maintenance of a viable domestic uranium industry." The National Mining and Minerals Policy Act of 1970 encourages and fosters the private enterprise development of our nation's natural resources. To meet the national intent, a cap on the growth rate of normal feed material supplied by the ore producers will be established ∽ 16,500 MTU. The rate of expansion for normal feed material will be limited to 1/2 the annual expansion of nuclear power growth.

## 5.0 Plan Technology Development and Production Implementation

The requirements for this section are that each process proponent must submit for consideration a program plan for the respective technology which will permit a decision in the late 1980's time frame on plant deployment which could occur in the early to mid 1990's.

Each program plan submitted must clearly show the program phases and engineering and development costs required to bring a production plant on line. The critical path should be clearly identified and the major participants, proposed management team and structure, and their program responsibilities must be identified. Cost for the programs should be reported on a yearly basis for the present through the start up of a nominal 9 million SWU/yr production plant.

A crucial step for project success is technology transfer from the winning proponent to industry and to the team that will implement the technology. A clear identification of the necessary management structure for its implementation must be presented. Each proponent should discuss their proposed project management structure, including key personnel assignments. The relative level of participation and decision making by the program participants will change as the DM program progresses, and the projected designated responsibilities should be outlined. A similar analysis should be done in order to define the role of the participants in the R&D program.

The evaluation for this section will be based on consideration of seven major areas, with points awarded in the first five.

1. Program Plan and Development Strategy
2. Proposed Management Team
3. Operational flexibility in changing product assay, feed assay, and tails assay
4. Capacity Expansion, SWU Cost vs. Capacity
5. Development of Industrial Vendor Rate
6. Engineering and Development Costs
7. Program Schedule

Risk is included in each area as part of the consideration. Points for deployment date and development costs associated with program schedule are incorporated in Section 4. The program plan should be structured to result in the earliest possible date for start up of a production plant consistent with the constraints of logical progression through a demonstration module phase and a plant demonstration facility phase. Other attributes of a good program plan are:

1. Definition of how the technology development with involvement of private industry, will proceed in logical steps from the current status to start up of a production plant.

2. Identification of major milestones and decision points.
3. Use of parallel development wherever possible to minimize time required.
4. Identification of major participants and proposed program management structure.
5. Identification of relevant experience and qualifications in constructing and operating advanced technology systems and conducting major facilities and goal oriented R&D programs.
6. Projection of reasonable expenditure rates.
7. Minimization of high technical risk components on critical paths.
8. Explanation of how issues not explicitly addressed in the DM will be resolved.

A viable program schedule should include:

1. Clear identification of the critical path.
2. Identification of lead times for major equipment and facilities purchases.

In defining the proposed management team, care should be taken to be as specific as possible in elaborating the management structure responsibilities and areas of authority. As much as possible, specific key personnel for the DM program should be shown in their respective boxes as well as the qualifications and degree of authority of the team in order to permit the PEB to judge the credibility of the proposed team and the risks they feel this team would have in implementing the program plan, schedule and costs.

Table 5.1 shows a breakdown of the points for the major areas considered in this section and provides a sheet for tabulation of award points.

Table 5.1

EVALUATION OF TECHNOLOGY DEVELOPMENT AND PRODUCTION IMPLEMENTATION

| MAJOR AREA | MAXIMUM POSSIBLE POINTS | POINTS AWARDED |
|---|---|---|
| Development Strategy | | |
| Operation flexibility in changing product assay, feed assay, and tails assay | | |
| Capacity expansion, SWU Cost vs. capacity | | |
| Development of industrial vendor base | | |
| Management Team | | |
| Total | 15 | |

TOTAL POINTS AWARDED __________

## 6.0 Proliferation and Safeguards

### 6.1 Proliferation

A proliferation assessment will be prepared by an independent contractor. Each proponent should be prepared to discuss his baseline design for scenarios of both diversion of a large LEU plant for HEU production and clandestine construction of a small HEU plant using the same technology.

### 6.2 Safeguards

A Safeguard Assessment Report will be prepared by Brookhaven National Laboratory (BNL). The baseline plant design and supporting large plant design studies will serve as a basis for this assessment. The LASL safeguard assessment and other studies may also be submitted.

## 7.0 Environmental, Health and Safety

A generic environmental assessment will be prepared by Pacific Northwest Laboratory (PNL) which is in compliance with NEPA regulation. The baseline plant design and supporting large plant design studies will serve as a basis for the assessment.

# APPENDIX A

## DATA REQUIREMENTS FOR CONTENDING AIS PROCESSES

Table A-1

Science and Technology Base-Data Package Requirements for PSP

| SUBCATEGORY | DATA REQUIREMENTS |
|---|---|
| 1. Feed Source | a. Design and operation of current experimental feed source. |
| | b. Source plate lifetime and fraction of source plate utilized. |
| | c. Source yield and uniformity of source plate surface as a function of time. |
| | d. Direction spectrum and energy distribution of vaporized atoms. |
| | e. Source plate energy consumption. |
| | f. Fraction of vapor refluxed to source plate. |
| | g. Fraction of neutrals that are ionized. |
| | h. Energy expended per ion formed. |
| | i. Lifetime of RF ionization antenna. |
| | j. Ionization cross section for single and double ionization. |
| | k. Fraction of double ions formed. |
| | l. Scaling requirements. |
| | m. Integration issues. |
| 2. Process Chamber | a. Design and operation of current superconducting magnet. |
| | b. Magnetic field uniformity over the plasma cross section. |
| | c. Charge exchange cross sections for neutral/ single ion exchange and for single ion/ double ion exchange. |
| | d. Hard body collision cross sections. |
| | e. $T_5$ vs drive field. |
| | f. $T_5/T_8$ vs drive field. |
| | g. Scaling requirements. |
| | h. Integration issues. |
| 3. Electromagnetic Signals | a. Design and operation of induction drive coil. |
| | b. Radial distribution of drive field strength. |
| | c. Power consumption of drive coil. |
| | d. Scaling requirements. |
| | e. Integration issues. |

Table A-1 (Continuation)

Science and Technology Base-Data Package Requirements for PSP

| SUBCATEGORY | DATA REQUIREMENTS |
|---|---|
| 4. Extraction/Collection | a. Design and operation of current collectors.<br>b. Variation of enrichment with cut.<br>c. Fraction of process stream deposited on guard tabs and support structure.<br>d. Enrichment achieved in subscale experiments.<br>e. Collector lifetime, cleaning requirements, replacement frequency.<br>f. Collected material lost to vaporization and thermionic emission.<br>g. Treatment of recycle material Scaling requirements.<br>h. Scaling requirements.<br>i. Integration issues. |
| 5. Tails treatment/Staging | a. Design and operation of tails collection.<br>b. Frequency of tails removal.<br>c. Tails handling and storage procedure.<br>c. Scaling requirements.<br>d. Integration issues. |
| 6. Process Model | a. Description of model and phenomena included.<br>b. Complete listing and justification of assumptions made in developing the model.<br>c. Comparisons of model predictions with experimental results. including error analysis.<br>d. Comparison of model predicted enrichments with measured results for experimental performance that most nearly represents plant conditions. |

Table A-2

Science and Technology Base-Data Package Requirements for AVLIS

| SUBCATEGORY | DATA REQUIREMENTS |
|---|---|
| 1. Feed Source | a. Design and operation of current experimental feed source. |
| | b. Feed mechanism operation and boat and E-beam lifetime. |
| | c. Vaporization rates and uniformity with source length. |
| | d. E-beam power requirements and boat cooling requirements. |
| | e. Vapor velocity distribution. |
| | f. Scaling requirements. |
| | g. Integration issues. |
| 2. Process Chamber | a. Design and operation of background ion collector currently used. |
| | b. Fraction of background ions created. |
| | c. Fraction of vapor refluxed to source. |
| | d. Fraction of metastables created prior to irridation. |
| | e. Fraction of atoms available in the ground and 620 $cm^{-1}$ states. |
| | f. Fraction of material ionized and measured absorption cross sections. |
| | g. Geometry of current radiation zone including anode and tab placement. |
| | h. Means of addressing hyperfine states and measured results. |
| | i. Measured charge exchange cross section. |
| | j. Scaling requirements. |
| | i. Integration issues. |
| 3. Electromagnetic Signals | a. Design and operation of current experimental lasers. |
| | b. Laser pulse length, wavelength, energy, pulse rate, and beam diameters currently used. |
| | c. Beam train transmission. |
| | d. Efficiency and mean time between failures of current lasers. |
| | e. Propagation characteristics of laser beams on resonance in process media. |
| | f. Cleaning requirements of laser dyes. |
| | g. Scaling requirements. |
| | h. Details of fluence source multiplexing. |
| | i. Integration issues. |

Table A-2 (Continuation)

Science and Technology Base-Data Package Requirements for AVLIS

| SUBCATEGORY | DATA REQUIREMENTS |
|---|---|
| 4. Extraction/Collection | a. Design and operation of current extractors.<br>b. Materials used and lifetimes achieved, replacement frequency.<br>c. Measured effects of sputtering and thermionic emission.<br>d. Fraction collected.<br>e. Enrichment achieved with current experiments.<br>f. Treatment of recycle material from tabs and support structure.<br>g. Measured values of stripping efficiency.<br>h. Scaling requirements.<br>i. Integration issues. |
| 5. Tails Treatment/Staging | a. Design and operation of tails collection system.<br>b. Tails handling and storage system.<br>c. Scaling requirements.<br>d. Integration issues. |
| 6. Process Model | a. Description of model and phenomena included.<br>b. Complete listing and justification of assumptions made in developing the model.<br>c. Comparisons of model predictions with experimental results including error analysis.<br>d. Comparison of model predicted enrichments with measured results for experimental performance that most nearly represents plant conditions. |

Table A-3

Science and Technology Base-Data Package Requirements for MLIS

| SUBCATEGORY | DATA REQUIREMENTS |
|---|---|
| 1. Feed Source | a. Design and operation of current experimental feed system.<br>b. Nozzle designs tested.<br>c. Material throughputs achieved.<br>d. Uniformity of temperature, pressure and monomer number density at the nozzle exit.<br>e. Scaling requirements.<br>f. Integration issues. |
| 2. Process Chamber | a. Design and operation of current process chamber.<br>b. Fraction of $UF_6$ condensed prior to and in the process chamber.<br>c. Fraction of $UF_6$ that can be addressed in the process.<br>d. Temperature dependence of enrichment.<br>e. Fraction of material in the boundary layer.<br>f. Spectroscopy of $UF_6$ for first and second color ir lasers at process fluence.<br>g. Ultraviolet spectroscopy of $UF_6$ with and without ir enhancement.<br>h. Measured cross sections for both ir and uv lasers.<br>i. Scaling requirements.<br>j. Integration issues. |
| 3. Electromagnetic Signals | a. Design and operation of current experimental lasers.<br>b. Laser pulse length, wavelengths, energy, pulse rate and beam diameters used.<br>c. Details of fluence source multiplexing.<br>d. Efficiency and mean time between failures of current lasers.<br>e. Progagation characteristics of laser beams in the process media.<br>f. Gas laser cleanup requirements.<br>g. Scaling requirements.<br>h. Integration issues. |

Table A-3 (Continuation)

Science and Technology Base-Data Package Requirements for MLIS

| SUBCATEGORY | DATA REQUIREMENTS |
|---|---|
| 4. Extraction/Collection | a. Design and operation of collectors.<br>b. Pressure drop, loading rate and cleaning frequency.<br>c. Material lost to back reaction and exchange.<br>d. Scavenger gas reactions and products formed.<br>e. Enrichment achieved with current experiments.<br>f. Collector efficiency and replacement frequency.<br>g. Scaling requirements.<br>h. Integration issues. |
| 5. Tails Treatment/Staging | a. Interstage gas cleanup requirements.<br>b. Compressor requirements and design of current units.<br>c. Tails treatment and storage.<br>d. Integration issues. |
| 6. Process Model | a. Description of model and phenomena included.<br>b. Complete listing and justification of assumptions made in developing the model.<br>c. Comparisons of model predictions with experiment results including error analysis.<br>d. Comparison of model predicted enrichments with measured results for experimental performance that most nearly represents plant conditions. |

# APPENDIX B
# OUTLINE OF UCC-ND AIS
# PROCESS ASSESSMENT BASES AND ASSUMPTIONS

The assumptions and bases outlined below are intended to be utilized in the mid-FY 1982 UCC-ND assessment of the AIS processes. The information is presented in three categories: Plant Description, Guidelines for Cost Presentation, and Economic Ground Rules.

## Plant Description

- The annual separative work capacity will be approximately 9 million SWU/yr (8.5 to 9.5 million SWU/yr).
- Normal assay feed will separated into an LWR fuel grade product (3.0 to 3.2% $^{235}$U) and a tails stream of nominally 0.1% $^{235}$U (0.08 to 0.12%).
- The plant will be the first of a kind to employ the AIS technology.
- The reference plant will be a shared site facility, located at the DOE's enrichment plant site in Oak Ridge, Tennessee.

## Guidelines for Cost Presentation

- Costs will be assigned for all necessary steps from the common starting point of uranium ore concentrate and to the common end point of reactor-grade enriched oxide.
- Where commercial feed and product technology and/or facilities exist, it will be assumed that these operations will remain in the private sector, and commercial prices will be the basis for assigning costs (see next section).
- Facilities for specialized uranium handling operations not now in the private sector will be included within the enrichment plant design and cost estimate.
- Capital costs will include allowances for engineering, contingency, and interest during construction.
- The allowance for contingency will be estimated by the Engineering organization as a part of the large plant studies which have recently been initiated. Engineering will use the contingency matrix methodology applied most recently to the AIS Development Module conceptual design studies wherein appropriate contingency percentages are assigned to each second number account in the cost code of accounts. Contingency percentages range from 15% for standard equipment up to 100% for certain special facility equipment or components where limited design or high technical uncertainty exists. This analysis will be separately performed for each process by a team including the design manager, the cost engineer, and the lead design engineers.

Economic Ground Rules

- The annual charge rate on capital will be 11.02% representing a 25-year write-off at 10% per year interest rate.
- Costs will be stated in end-of-FY 1981 dollars.
- The costs of various chemical conversion steps for uranium and uranium compounds will be based on commercial prices such as those identified in the feed cost studies* recently done for the AIS program by the staff of the Paducah Gaseous Diffusion Plant. Lower costs which might result from developing and implementing advanced technology and/or from capacity increases will be treated as uncertainty analysis inputs.
- The costs of uranium ore concentrate will be taken as \$30/lb $U_3O_8$.
- The cost of electric power will be 30 mills/kWh.
- Operating and maintenance labor costs will be based on current ORGDP experience.

---

* Bewley, H. D., et al, Feed and Product Cost Study for Advanced Isotope Separation Processes, Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, February 2, 1981 (K/ET-731), UNCLASSIFIED; Carpenter, K. W., et al, Overview of Uranium Processing Technology Interfacing Uranium Enrichment Systems (U), Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, March 16, 1981 (K/ET-731), CONFIDENTIAL; Bewley, H. D., et al, Production of AVAIS Feed from Tails $UF_6$, Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, February 2, 1981 (K/ET-733), UNCLASSIFIED.

Question 24. When does DOE plan to announce the selection of one of the processes for engineering development?

Answer 24. The target date for process selection is April 1982.

Question 25. What criteria are being used by DOE to evaluate the AIS processes and what are the relative weights being attached to each of the criterion?

Answer 25. The information requested is contained in the Advanced Isotope Separation Program selection criteria document provided in answer to question 23.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

April 21, 1982

Dr. Shelby T. Brewer
Asst. Secty. for Nuclear Energy
U.S. Department of Energy
Washington, DC 20585

Dear Shelby:

We appreciated having Dr. Dillon and Mr. Voigt testify on the Department of Energy's Uranium Enrichment programs at the Subcommittee's FY 1983 budget review hearing on March 30, 1982. Chairman Bouquard and the Minority Members of the Subcommittee would like to supplement the record of the hearing with some additional questions they have regarding the programs. We appreciate your cooperation on this matter and we hope that this information can be provided by May 14, 1982.

We also request that the Subcommittee be provided with one copy of each report and publication which is wholly or partially funded by the Office of Uranium Enrichment and Assessment or its contractors, as well as OUEA newsletters, press releases, and program review announcements commencing from the beginning of fiscal year 1982.

If you have any general questions regarding these request, please contact me at 225-8056. If you have any questions regarding the specifics, please contact Dr. Harlan Watson of the Subcommittee staff at 225-3472.

Sincerely,

Jack

JOHN V. DUGAN, JR.
Staff Director
Subcommittee on Energy Research
and Production

JVD:mpa
Enclosures

## QUESTIONS SUBMITTED BY CHAIRMAN BOUQUARD

## DEMAND AND SUPPLY OF URANIUM ENRICHMENT SERVICES

1. How does the current projected production by DOE enrichment plants compare with (i) the 1980 estimates of future production, (ii) the 1978 estimates of future production and (iii) the 1974 estimates of future production?

2. What is the present production capacity of the existing enrichment plants? And how does this compare with the actual production from these plants?

3. When is it expected that the actual production at these facilities will equal their total capacity?

4. What is the projected surplus production capacity during the next ten years?

5. What problems have arisen as a result of operating the existing enrichment facilities at or below design capacity?

6. How much of the demand requirements for the SWU's during fiscal year 1982 and 1983 will be supplied from the stockpile?

7. What is the present size of the stockpile and, given the projected demand and production schedules, what is the projected size of the stockpile for the next ten years?

8. How much of the projected demand is anticipated to be supplied by the Department of Energy's Uranium Enrichment Program through (i) its three existing plants, (ii) the Portsmouth Gas Centrifuge Facility, (iii) construction of additional plants following the Portsmouth Facility, and (iv) the replacement of its existing facilities?

9. Of the amount under contract, how much of the projected demand is for contracts for nuclear power plants which have been (i) cancelled and (ii) deferred?

10. How many domestic and foreign contracts for DOE enrichment services have been cancelled or terminated in the last 5 years, and how much production was each contract for?

11. During the last 5 years, how many enrichment contracts which have expired by the terms of such contracts have not been renewed?

## URANIUM ENRICHMENT SERVICES REVENUES

12. Why are funds being provided from the Department of Defense in FY 1983 for the first time?

13. Dr. Dillon, your chart on page 3 of your testimony indicates that your revenues for FY 1983 will increase by $202.5 million, or by $103.5 million if the Department of Defense funds are excluded. What is the basis for this substantial revenue increase? Are we going to be selling more SWUs or just charging more or what?

14. Why is DOE proposing to carry over some $65.654 million to FY 1984 rather than applying this amount to other activities within the enrichment program or using this to support other programs within the Department?

15. What are the projected charges for enrichment services during fiscal years (i) 1982, (ii) 1983, (iii) 1984, and (iv) 1985?

16. What factors affect the projected charges for enrichment services?

17. What portion of the current and projected charges are attributable to the cost of constructing the Portsmouth Gas Centrifuge Facility?

18. What effect will payment from government customers have on the cost of enrichment services for commercial customers?

19. What was the value of the enrichment services provided to government customers for each of the last five years?

20. What is the difference in the price of SWUs charged to government customers from the price charged commercial customers and what is the statutory basis for such a distinction?

21. On page 131 of Volume 4 of the Department of Energy Fiscal Year 1983 Congressional Budget Request Book it is stated that "Additionally, 1.2 million SWU is sold to government customers at a value of $109,000,000. $43,346,000 of this amount is credited against the Uranium Enrichment Program..." What is meant by "crediting" such sums "against the Uranium Enrichment Program?"

22. Given current knowledge of the Fiscal Year 1982 program, what are the projected revenues and program costs and how do such revenues compare with estimates made last year by (i) the Office of Management and Budget, and (ii) the Congressional Budget Office?

23. Withdrawals from the stockpile will be sold at a price equal to the current price for new production, resulting in a profit for each sale, consisting of the difference in the cost of production and the sale price. How are such profits accounted for in the Department's budget, and what are such funds used for?

24. The fiscal year 1983 budget request includes for the first time estimates for revenues from sale to government customers. How were such services for government customers funded in the past, and where does such funding appear in prior budgets?

## URANIUM ENRICHMENT DEMAND CHARGES

25. Has DOE considered asking TVA to offer a discount on this surplus electricity to make it attractive for a utility to offset oil or gas fueled power production? In this way, the DOE and TVA could be serving the national interest in lowering oil and gas consumption pursuant to the Powerplant and Industrial Fuel Use Act, and could be mitigating this 25% capacity charge. Theoretically, TVA could offer up to a 24% discount and still come out ahead.

26. Would DOE favor lifting the restriction in Section 44 of the Atomic Energy Act, which prohibits DOE from directly selling its excess contract electricity? Please explain.

27. Since TVA is restricted in considering the power needs of parts of the region beyond its legal ability to serve, should the Congress consider legislation to require a study of power needs and utility capacity in and around the Southeastern region of the United States?

28. What power budget level would be required to take the contract amounts of electricity and correspondingly, how much would the stockpile grow?

29. If the contract amount of electricity is taken, how much extra would have to be appropriated to cover the power costs?

30. Have you asked TVA to look into various options, for example, wheeling the power through a utility to whom TVA may sell power to other government-funded complexes such as the Princeton Plasma Physics Lab, Brookhaven, Fermi Lab, etc.?

31. In view of the past success DOE has had in obtaining capacity charge relief from OVEC, what probability do you think the Department has in obtaining relief of the $22 million in demand charges anticipated for FY 1983? When does DOE expect to receive OVEC's decision regarding these charges?

32. Will DOE's current negotiations with its power suppliers limit DOE's ability to get the power needed for its diffusion plants after 1989, should GCEP not be built as planned?

## ADVANCED GAS CENTRIFUGE (AGC) TECHNOLOGY

33. Please describe in greater detail what you are trying to accomplish in the AGC program.

34. What are the objectives of the AGC program for the Set IV, Set V, and Set VI developments?

35. What is the plan and schedule for deploying Set IV centrifuges?

36. What are the anticipated accomplishments in FY 1982 and FY 1983 for the AGC program?

37. What are the details of the funding requested in FY 1983 for the gas centrifuge process development and demonstration program?

38. What is the GCEP Centrifuge Design Verification Schedule?

39. What is the basis for the stated 50 percent improvement of the advanced technology centrifuge over the baseline centrifuge?

40. What is the total estimated cost for the development for each of the Set III, Set IV, Set V, and Set VI centrifuges?

41. What portion of the cost of producing a SWU is attributable to the cost to date of developing centrifuge technology?

## ADVANCED ISOTOPE SEPARATION (AIS)

42. What is the Process Evaluation Board's schedule for selection of one of the AIS processes?

43. What methodology is the PEB using to make such a selection?

44. Would a delay in choosing one AIS technology delay the deployment of a future full-scale production plant?

45. What is the schedule for the engineering development of the selected AIS process?

46. What additional developmental stages will the AIS program have to complete before the selection of an AIS technology could be made on the basis of full production costs?

47. What will be the cost of the engineering development of the chosen process?

48. What would be the cost of delaying the AIS selection date and funding the additional work needed to increase confidence that the chosen AIS technology will be the most economically viable one?

## PRIVATIZATION OF THE URANIUM ENRICHMENT PROGRAM

49. What is the status of the consideration of the "privatization" of the Uranium Enrichment Program?

50. What role, if any, has the private sector played in these considerations?

51. What expressions of interest have been made by the private sector in regard to assuming the responsibility for providing such service?

## U.S. INVOLVEMENT IN THE PROPOSED AUSTRALIAN URANIUM ENRICHMENT FACILITY

52. What is the present status of efforts to assist private enterprise in the United States to obtain the proposed contract for the Australian uranium enrichment facility?

53. What, if any, legal steps must be taken to make the enrichment technology available to the private sector in order for domestic firms to compete for the proposed Australian facility?

54. What, if any, legal steps must be taken in order for domestic firms to offer for sale to Australia the uranium enrichment technology?

55. What assistance does the Administration propose to provide domestic firms in order to support their efforts to obtain this contract?

56. What is the relationship between the Administration's interest in promoting American participation in the proposed Australian uranium enrichment plant and the present consideration of transferring the domestic uranium enrichment program to the private sector?

57. What is the relationship between the Administration's interest in promoting American participation in the proposed Australian uranium enrichment plant and the Administration's plan for (i) continued funding of the Portsmouth gas centrifuge plant, and (ii) continued operation of the existing uranium enrichment facilities?

58. What is the estimated impact of the entry of an Australian uranium enrichment program into the world market on the estimated demand for United States enrichment services, and what is the basis for such estimates?

59. Is the Administration engaged in any government-to-government discussions of any type with Australia regarding the potential availability of the uranium enrichment technology, and if so, could you summarize such discussions?

60. One of the major factors in awarding the Australian contract is reported to be the degree of assurance which can be provided that a market for such enriched uranium exist. What proposals are the Administration prepared to make to assure the availability of a market?

## POTENTIAL PARTICIPATION OF MEXICO IN GCEP AND FOREIGN ENRICHMENT SALES

61. To what extent is it true that Mexico might become a partner in GCEP?

62. Why couldn't Mexico obtain enrichment services from the U.S. even if it wasn't a partner in GCEP?

63. What currently prevents the U.S. from "packaging" uranium enrichment services into a transaction which includes uranium enrichment services, a reactor, raw material, financing, and so on?

64. To what extent does the inability to provide such a nuclear power package deal restrain U.S. sales of U.S. enrichment services?

65. Does DOE plan to facilitate the "packaging" of enrichment services along with other related fuel cycle services to meet the needs of the marketplace and, if so, how does it plan to proceed?

66. What are the prospects for increasing foreign sales? What are factors that inhibit expanded sales?

67. How many foreign contracts for enrichment services were signed in Fiscal Year 1981, and how many contracts with foreign users are expected to be signed in Fiscal Year 1982 and Fiscal Year 1983? Please specify (i) the type of contract involved and (ii) the amount of separative work involved.

68. The December 2, 1980 report entitled Uranium Enrichment Management Review recommended "that DOE should immediately consider the following:

    a) Take more aggressive steps to renegotiate contracts for the electric power needed to run the diffusion plants;

    b) Conduct a more formally organized and rigorous investigation of the minimum level of operating the diffusion plants;

c) Confirm a full commitment to complete the first two buildings of the gas centrifuge project as fast as economically practicable;

d) Give the enrichment enterprise control over the management of the advanced isotope separation research and development program;

e) Support legislation to establish a revolving fund;

f) Evaluate the practicality of establishing the enrichment enterprise as an independent agency similar to the Tennessee Valley Authority (TVA)."

It was further recommended "that the following steps be taken by the Office of Uranium Resources and Enrichment (OURE):

a) Press for negotiation of a project stabilization agreement for the Portsmouth centrifuge construction project to diminish the possibility of jurisdictional and other labor union disputes;

b) Update its strategy on an annual basis;

c) Develop a model for use in long-range strategic planning and policy studies;

d) Evaluate a probabilistic method of forecasting enrichment demand;

e) Devote more resources to planning and marketing activities;

f) Reassess cancellation charge policies to eliminate the current situation that promotes cancellation of its own rather than competitors' contracts due to low DOE charges;

g) Supplement its auditing procedures by engaging outside auditors to lend added credibility to the enrichment enterprise;

h) Develop a set of overall objectives jointly with higher management;

i) Clarify the information needs of higher levels of management."

What has DOE done with regard to the implementation of these recommendations?

69. What are the internal audit procedures and techniques used to estimate and control expenditures?

70. How does the Office of Uranium Enrichment and Assessment use computer models in its decision making?

71. How are the models validated, and by whom?

72. What has prior validation experience shown? Has it proven models to be accurate or inaccurate? Can you cite specific examples?

73. What is the Department's response to the criticism by some that the computer models used are "old and creaky?"

74. How does the Office of Uranium Enrichment and Assessment (OUEA) know that the huge complex is being managed well? How does OUEA measure performance of the enrichment enterprise? How does OUEA know that the two operating contractors, Union Carbide Corporation and Goodyear Atomis Corporation, are being managed well?

75. Does OUEA have specific goals which contractors must meet?

## REVOLVING FUND LEGISLATION

76. Does the present budget approval process negatively impact the success of the current Uranium Enrichment Program?

77. Would a revolving fund significantly help the Office of Uranium Enrichment and Assessment carry out its objectives more expeditiously?

78. Would the program be as responsive to policy changes, both in the Executive branch and the Legislative branch under a revolving fund?

## URANIUM RESOURCES AND STATE OF THE DOMESTIC URANIUM PRODUCING INDUSTRY

79. What is the current price of uranium, and how has it fluctuated over the past decade?

80. What is the current total uranium (i) mining and (ii) milling capacity in the United States, and how does this figure compare with total capacity during the last 10 years?

81. Given the present estimate of reserves in the United States and the number of reactors in operation or under construction, what is the ability of existing reserves to supply the needs of all operating and planned power reactors in the United States during their estimated useful life, and how many additional light water reactors could be fueled and operated with such reserves?

82. What is the total amount of foreign uranium purchased last calendar year by domestic firms for use in the United States, and what percentage of domestic requirements is this amount?

83. What is the total amount of domestic uranium sold to buyers for export?

84. Dr. Dillon, your testimony indicates that there are and have been restrictions on the enrichment of foreign-origin uranium for domestic end use. Are there similar restrictions on the amount of uranium that can be imported?

85. Is the Department considering restricting the amount of foreign-origin uranium which can be enriched in the United States pursuant to its charter in the Atomic Energy Act "to assure the maintenance of a viable domestic uranium industry..." (Sec. 161(v))?

86. How many countries are presently supplying uranium to domestic utilities, and what is the projected stability of these sources?

## URANIUM RESOURCES ASSESSMENT PROGRAM

87. What will be the achievements of the Uranium Resource Assessment Program during Fiscal Year 1982?

88. What specific activities are scheduled to be performed under this program during Fiscal Year 1983?

89. What have been the accomplishments of the Uranium Resource Assessment Program since its foundation?

90. What has been the increase in the estimated uranium reserves in this country over the last 10 years and to what extent has any such increase been due to the efforts of the Uranium Resource Assessment Program?

91. What is the total amount of federal funds expended on the Uranium Resource Assessment Program from its inception through Fiscal Year 1982?

QUESTIONS FROM MINORITY MEMBERS

1. On March 8, at the FY'83 appropriations hearings, Shelby Brewer testified that a viable uranium production industry is comprised of the companies that remain after market adjustments have been made. Is it DOE's position that a few companies' survival, with heavy reliance on foreign suppliers, equates with a viable industry?

2. The Atomic Energy Act requires the DOE to maintain a viable uranium industry. What basis in the Act do you have for this new definition of a viable uranium industry?

3. What then, specifically, constitutes a viable uranium industry? What should the industry be capable of doing in terms of exploration and producing capability?

4. What do you believe it would take to reverse the decline of the domestic uranium industry?

5. Are you aware that nearly all recent uranium sales to U.S. utilities have been made by foreign producers?

6. Suppose that all of the new requirements for uranium were filled by imports. What action would you recommend be taken and when would you recommend that action be taken?

7. What impact do these recent foreign sales have on the U.S. producer?

8. Are you aware that a major U.S. producer has elected to purchase foreign uranium to meet his contractual commitments rather than produce? Are you aware that foreign governments have approached other major producers offering to sell substantial quantities of foreign uranium at prices below U.S. production costs?

9. What does this development (in Question 8) indicate about the current status of the U.S. producer?

## ENRICHMENT PRICING

10. Has DOE lost enrichment business to foreign competition as a result of lower prices or as a result of anticipated price increases by DOE?

11. Is DOE aware of additional enrichment work which will be lost to foreign sources of supply or which is in jeopardy as a result of current or anticipated price policy?

12. Under the Atomic Energy Act of 1954, the price of U.S. enriching services has been and continues to be based upon the policy of "recovery of the government's cost over a reasonable period of time." In application, the calculation of the price of a unit of enrichment (Separative Work Unit or "SWU") is directly dependent upon the projected costs versus the anticipated sales backlog over a rolling 10-year advance period. Any error in forecasting or loss of anticipated sales to more competitive pricing automatically requires higher, less competitive prices for enrichment.

Does DOE view this policy as constraining its ability to market its services? How would you modify this statutory requirement? How would such a modification affect domestic electricity consumers who pay for nuclear-generated power?

13. The current DOE forecast of future enrichment services required is questioned by most independent authorities on nuclear power and they claim that your projections contain enrichment work for reactors which have, by public announcement, been cancelled or indefinitely deferred. Would you comment on this charge? What limits of error are placed on your forecasts, and to what extent does this variance increase the price in order to achieve the "full cost recovery" goal?

14. The only new foreign contract for enrichment services for a foreign reactor has come from Egypt. Does DOE have plans to assert a more aggressive marketing position, realizing the real world of overcapacity and competitive pricing?

15. In 1981, DOE recorded $38.1 million of net revenue resulting from the sale of enriched inventory, previously produced under the "split tails" option, equivalent to 1.25 million pounds $U_3O_8$. This transaction is in direct competition with U.S. uranium producers. In their current projections of enrichment prices, to what extent does DOE depend upon the revenues from such future sales of government-owned inventory?

16. Recognizing the considerably greater cost efficiency of the gas centrifuge process over the gaseous diffusion process, should not the research and development costs of this project be accumulated and subsequently written off in conjunction with the capital costs when this project assumes production status as a means of "holding the line" on current enrichment prices?

17. In the event that continued erosion of the DOE enrichment backlog does not support the need to maintain the current diffusion capacity until the centrifuge project reaches production capacities (if indeed this is not already the situation), has DOE projected the impact on enrichment prices that an early phasing out of diffusion capacity would entail? Would not the cost ramifications of such rescheduling make the continuance of a competitive enrichment price the preferable course?

## AIS

18. As you know, DOE has under consideration three AIS technologies and is expected to choose one for engineering development in April. Has DOE considered designating a backup process in case the primary process is not successfully developed? What would be the criteria for a backup process?

## QUESTIONS FOR MR. VOIGT

19. Section 161(v) of the Atomice Energy Act, which provides your authority to operate the DOE uranium enrichment program, says the following:

> And provided further, that the Commission, to the extent necessary to assure the maintenance of a viable domestic uranium industry, shall not offer such services for source or special nuclear materials of foreign origin intended for use in a utilization facility, within or under the jurisdiction of the United States.

The latest EIA report to the Congress contained some very disturbing conclusions about the health of the U.S. uranium mining and milling industry:

> Under the current Federal policy, which will allow unrestricted imports of foreign uranium beginning in 1984, foreign suppliers could capture about half of the U.S. market by the 1990's, implying a domestic uranium industry reduced to about half its current size.

If half of the domestic utilities will be utilizing foreign uranium, which you are prohobited from enriching, what do you estimate will be the amount of capacity that you can enrich?

**Department of Energy**
**Washington, D.C. 20585**

May 21, 1982

Mr. John V. Dugan, Jr.
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Dugan:

Enclosed are the answers to questions you submitted on April 21, 1982, following Dr. Dillon's and Mr. Voigt's March 30 testimony on the Department's Uranium Enrichment programs.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

for Thomas W. Pretorius

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosures

cc: Ms. Mary Bly
Committee on Science
and Technology

COMMITTEE ON SCIENCE AND TECHNOLOGY

Subcommittee on Energy Research and Production

QUESTIONS AND ANSWERS

Following the

March 30, 1982 Hearing

## COMMITTEE ON SCIENCE AND TECHNOLOGY

## Subcommittee on Energy Research and Production

## QUESTIONS AND ANSWERS

PAGE NUMBER

### QUESTIONS SUBMITTED BY CHAIRMAN BOUQUARD

Demand and Supply of Uranium Enrichment Services ................ 1 - 14
Questions 1 - 11

Uranium Enrichment Services Revenues ............................ 15 - 28
Questions 12 - 24

Uranium Enrichment Demand Charges ............................... 29 - 37
Questions 25 - 32

Advanced Gas Centrifuge (AGC) Technology ........................ 38 - 47
Questions 33 - 41

Advanced Isotope Separation (AIS) ............................... 48 - 56
Questions 42 - 48

Privatization of the Uranium Enrichment Program ................. 57 - 60
Questions 49 - 51

U.S. Involvement in the Proposed Australian Uranium Enrichment Facility ............................................. 61 - 70
Questions 52 - 60

Potential Participation of Mexico in GCEP and Foreign Enrichment Sales ................................................ 71 - 90
Questions 61 - 75

Revolving Fund Legislation ...................................... 91 - 94
Questions 76 - 78

Uranium Resources and State of the Domestic Uranium Producing Industry .......................................... 95 -103
Questions 79 - 86

Uranium Resources Assessment Program ............................ 104 -110
Questions 87 - 91

PAGE NUMBER

QUESTIONS FROM MINORITY MEMBERS

- - - - - ........................................................ 111 - 120
Questions 1 - 9

Enrichment Pricing ............................................ 121 - 130
Questions 10 - 17

Advanced Isotope Separation ................................... 131 - 132
Question 18

Questions for Mr. Voigt ....................................... 133 - 135
Question 19

Nuclear Energy
Office of Uranium Enrichment
and Assessment

May 10, 1982

QUESTIONS 1 - 91

QUESTIONS SUBMITTED BY CHAIRMAN BOUQUARD

QUESTIONS 1 - 11

# DEMAND AND SUPPLY OF URANIUM ENRICHMENT SERVICES

| | |
|---|---|
| Question 1. | How does the current projected production by DOE enrichment plants compare with (i) the 1980 estimates of future production, (ii) the 1978 estimates of future production and (iii) the 1974 estimates of future production? |
| Answer 1. | The requested data are shown in Table 1 for each year starting in FY 1982 through FY 1995, shown in million Separative Work Units. |

Table 1

Comparison of Projected Production
By DOE Enrichment Plants
(millions of SWU)

| Fiscal Year | 1974[1] Estimates | 1978 Estimates | 1980 Estimates | Current Estimates |
|---|---|---|---|---|
| 1982 | 25.2 | 23.4 | 20.6 | 9.8 |
| 1983 | 25.2 | 23.4 | 20.5 | 9.8 |
| 1984 | 25.7 | 25.4 | 21.5 | 16.7 |
| 1985 | 27.4 | 27.3 | 21.5 | 16.7 |
| 1986 | 27.6 | 27.9 | 23.5 | 16.7 |
| 1987 | 27.7 | 30.6 | 25.4 | 23.3 |
| 1988 | 27.7 | 33.9 | 25.4 | 24.1 |
| 1989 | 27.7 | 36.1 | 26.2 | 24.1 |
| 1990 | 27.7 | 36.1 | 28.0 | 26.0 |
| 1991 | 27.7 | 36.1 | 29.2 | 24.1 |
| 1992 | 27.7 | 36.1 | 30.5 | 26.1 |
| 1993 | 27.7 | 36.1 | 32.0 | 28.4 |
| 1994 | 27.7 | 36.1 | 33.3 | 30.5 |
| 1995 | 27.7 | 36.1 | 34.0 | 29.3 |

---

[1] Enrichment needs beyond that available from Government's three gaseous diffusion plants were assumed to be supplied by private industry.

Question 2. What is the present production capacity of the existing enrichment plants? And how does this compare with the actual production from these plants?

Answer 2. The design production capacity of the diffusion complex following completion of the Cascade Improvement and Cascade Uprating Programs will be 27.3 million separative work units per year. This capacity will be fully installed by the beginning of FY 1984. However, the total amount of power needed to operate the plants at this level is not under firm contract. The plants will produce 9.3 million separative work units per year in FY 1982 and FY 1983. These production levels represent 36 percent of the design capacity of the plants in those years.

In FY 1982 the production capacity of the gaseous diffusion complex, based upon contract power levels, is 14.7 million separative work units as compared to planned production of 9.8 million separative work units. In FY 1983 the production capacity, again based upon contract power levels, is 16.9 million separative work units as compared to planned production of 9.8 million separative work units. In FY 1982 the planned production represents about 67 percent of firm power capacity and in FY 1983 it represents about 58 percent of firm power capacity.

Question 3. When is it expected that the actual production at these facilities will equal their total capacity?

Answer 3. At this time, it is not anticipated that the gaseous diffusion plants will ever operate at their maximum capacity. The final 320 megawatts of power at the Portsmouth plant, which represents a production capability of about 0.9 million separative work units per year, has not been contracted for because the unit cost of this production is higher than that which can be achieved in the gas centrifuge enrichment plant.

In addition, the current operating plan, which was completed in December 1981, shows the diffusion complex producing a maximum of 23.7 million separative work units in FY 1988.

Question 4. What is the projected surplus production capacity during the next ten years?

Answer 4. Projected surplus gaseous diffusion production capacity based on existing contract power levels:

| | |
|---|---|
| FY 1982 | 4.9 million SWU |
| 1983 | 7.1 |
| 1984 | 4.4 |
| 1985 | 6.5 |
| 1986 | 6.5 |
| 1987 | 0 |
| 1988 | 0 |
| 1989 | 1.5 |
| 1990 | 0 |
| 1991 | 3.1 |

Question 5. What problems have arisen as a result of operating the existing enrichment facilities at or below design capacity?

Answer 5. Since October 1980, the gaseous diffusion complex has operated at a power level of 2660 megawatts. This level of operation will continue through FY 1983. This level is about 36 percent of the complex design power level.

Modifications to the complex's instrumentation and control systems have been made to facilitate operations at reduced power levels. As a result, the complex has so far not experienced excessive equipment failures or safety threatening incidents that are directly attributable to low power operation.

Cascade control, although sluggish, is being maintained. A production penalty of about 4 percent is being incurred in order to control the cascades. Solidification of the process gas ($UF_6$) has occured from time-to-time because of reduced temperatures in sections of process piping. These deposits of solid $UF_6$ are vaporized by using externally applied heat.

There is an ongoing program to identify the minimum acceptable risk power level. An updated report is expected to be issued in June 1982. At that time the operating contractors will make their recommendation as to what the minimum power level should be in light of the experience gained to date.

Question 6. How much of the demand requirements for the SWU's during fiscal year 1982 and 1983 will be supplied from the stockpile?

Answer 6. Projected demand to be supplied from stockpile:

| | |
|---|---|
| FY 1982 | 5.3 million SWU at 0.20% U-235 tails assay |
| FY 1983 | 5.6 million SWU |

Question 7. What is the present size of the stockpile and, given the projected demand and production schedules, what is the projected size of the stockpile for the next ten years?

Answer 7. Stockpile level, millions of SWU at 0.20% U-235 tails assay:

| | |
|---|---|
| Beginning Inventory | 32.0 |
| FY 1982 | 26.7 |
| 1983 | 21.1 |
| 1984 | 17.8 |
| 1985 | 12.0 |
| 1986 | 8.8 |
| 1987 | 9.3 |
| 1988 | 8.2 |
| 1989 | 8.7 |
| 1990 | 9.3 |
| 1991 | 8.5 |

A permanent working inventory of approximately 9.0 million SWU is required to operate the enrichment complex.

Question 8. How much of the projected demand is anticipated to be supplied by the Department of Energy's Uranium Enrichment Program through (i) its three existing plants, (ii) the Portsmouth Gas Centrifuge facility, (iii) construction of additional plants following the Portsmouth Facility, and (iv) the replacement of its existing facilities?

Answer 8. Table 2 shows the demand, for the mid-level, of the range of total worldwide separative work demand in Table 3 that is expected to be supplied by DOE. Of the 335 million separative units supplied through FY 1995, about 255 million will be supplied from the existing three gaseous diffusion plants (GDP's), about 50 million from the Portsmouth Gas Centrifuge Enrichment Plant (GCEP), with the balance obtained from DOE inventories. Of the 50 million SWU being supplied from GCEP through 1995, about 36 million SWU can be considered as substitution of GDP capacity. Between FY 1995 and 2000, it is anticipated that all demand can be met using the existing plants and GCEP by operating at a tails assay of 0.25% U-235 rather than the current 0.20% U-235. Hence, no new facilities are expected to be needed. During these five years, the GDP's will supply about 83 million SWU and GCEP will provide about 65 million SWU. About 44 million of the GCEP production during this period will be as substitution of GDP capacity. After 2000, the amount of new capacity required will be determined by the future economics of replacing existing plants with new capacity beyond GCEP and growth. The demand projection after FY 2000 shown in Table 2 at 0.25% U-235 tails assay indicates that new on-line capacity of about 2 million SWU per year would be needed by FY 2003 increasing to about 4 million SWU per year by FY 2005.

## Table 2

## Separative Work Demand to be Supplied by DOE (millions of SWU)

| Fiscal Year | At 0.20% Tails Assay | | At 0.25% Tails Assay | |
|---|---|---|---|---|
| | Annual | Cumulative | Annual | Cumulative |
| 1982 | 15 | 15 | | |
| 1983 | 15 | 30 | | |
| 1984 | 20 | 50 | | |
| 1985 | 24 | 74 | | |
| 1986 | 21 | 95 | | |
| 1987 | 24 | 119 | | |
| 1988 | 27 | 146 | | |
| 1989 | 24 | 170 | | |
| 1990 | 25 | 195 | | |
| 1991 | 25 | 220 | | |
| 1992 | 26 | 246 | | |
| 1993 | 29 | 275 | | |
| 1994 | 29 | 304 | | |
| 1995 | 31 | 335 | | |
| 1996 | 33 | 368 | 29 | 364 |
| 1997 | 33 | 401 | 29 | 393 |
| 1998 | 33 | 434 | 29 | 422 |
| 1999 | 35 | 469 | 31 | 453 |
| 2000 | 34 | 503 | 30 | 483 |
| 2001 | 33 | 536 | 29 | 512 |
| 2002 | 34 | 570 | 30 | 542 |
| 2003 | 35 | 605 | 31 | 573 |
| 2004 | 35 | 640 | 31 | 604 |
| 2005 | 38 | 678 | 34 | 638 |
| 2006 | 38 | 716 | 34 | 672 |

Table 3

Projected Annual Demand for Uranium Enrichment Services
(millions of SWU)

| Fiscal Year | Worldwide Demand1/ | U.S. Demand |
|---|---|---|
| 1982 | 18-19 | 9 |
| 1983 | 19-20 | 9 |
| 1984 | 22-25 | 12-13 |
| 1985 | 27-31 | 15-17 |
| 1986 | 25-30 | 12-15 |
| 1987 | 28-34 | 15-18 |
| 1988 | 33-41 | 19-24 |
| 1989 | 32-43 | 16-24 |
| 1990 | 33-38 | 16-18 |
| 1991 | 34-39 | 16-18 |
| 1992 | 34-41 | 16-18 |
| 1993 | 38-46 | 17-21 |
| 1994 | 39-49 | 17-21 |
| 1995 | 40-51 | 17-21 |
| 1996 | 43-54 | 19-23 |
| 1997 | 44-56 | 18-23 |
| 1998 | 46-60 | 20-24 |
| 1999 | 49-64 | 21-26 |
| 2000 | 50-66 | 21-26 |
| 2001 | 52-69 | 21-27 |
| 2002 | 54-72 | 21-28 |
| 2003 | 56-75 | 22-29 |
| 2004 | 58-79 | 23-30 |
| 2005 | 60-83 | 23-32 |
| 2006 | 62-85 | 24-32 |

---

1/ Includes U.S. demand; excludes Communist Bloc demand. Based on 0.20% tails assay.

Question 9. Of the amount under contract, how much of the projected demand is for contracts for nuclear power plants which have been (i) cancelled and (ii) deferred?

Answer 9. Of the 304 gigawatts of civilian nuclear power capacity under contract with the U.S. for enrichment services, about 40 gigawatts of nuclear capacity have been cancelled. These units are, therefore, not included in our projections of separative work demand. In addition, approximately 21 gigawatts of nuclear capacity represents nuclear units which have been indefinitely deferred by the utilities. Our forecast of separative work demand takes into account deferrals and delays in the schedules of nuclear power plants, contract terminations, expirations, and supply interruptions caused by political conditions.

Question 10. How many domestic and foreign contracts for DOE enrichment services have been cancelled or terminated in the last 5 years, and how much production was each contract for?

Answer 10.

| Contract Terminated | Notice of Termination Received | Termination Effective | Number of SWUs Terminated (millions of SWU) |
|---|---|---|---|
| 1. BASF | 6-7-78 | 6-7-78 | 1.0 |
| 2. Hamm | 12-13-78 | 12-13-78 | 1.7 |
| 3. Vahnum | 1-31-79 | 1-31-79 | 1.5 |
| 4. Philippsburg-2 | 2-21-79 | 2-21-79 | 0.8 |
| 5. Valdecaballeros | 2-23-79 | 2-23-79 | 0.9 |
| 6. Biblis | 4-2-79 | 10-1-82 | 2.1 |
| 7. Wuergassen | 4-30-79 | 5-15-84 | 1.1 |
| 8. Allen's Creek | 6-6-79 | 6-6-79 | 1.5 |
| 9. Iran-1 | 7-18-79 | 7-18-79 | 1.5 |
| 10. Iran-2 | 7-18-79 | 7-18-79 | 1.5 |
| 11. Oskarshamn-3 | 8-24-79 | 8-24-79 | 1.2 |
| 12. Tullnerfeld | - | 10-1-80 | 0.7 |
| 13. Gundremmingen | 6-4-81 | 6-4-81 | 0.2 |
| 14. Beznau-2 | 9-28-81 | 4-1-85 | 0.2 |

Question 11. During the last 5 years, how many enrichment contracts which have expired by the terms of such contracts have not been renewed?

Answer 11. None. A number of the enrichment contracts have expired by the terms of the contract, but in each case there already existed a follow-on DOE contract which provides continuing enrichment services for the reactors in question.

QUESTIONS 12 - 24

## URANIUM ENRICHMENT SERVICES REVENUES

Question 12. Why are funds being provided from the Department of Defense in FY 1983 for the first time?

Answer 12. Funds are being provided from the Department of Defense to offset the costs to the enrichment program of providing separative work for DOD. This transfer of funds is in line with the OMB's policy of each Department including their total funding requirements in their own budgets.

Question 13. Dr. Dillon, your chart on page 3 of your testimony indicates that your revenues for FY 1983 will increase by $202.5 million, or by $103.5 million if the Department of Defense funds are excluded. What is the basis for this substantial revenue increase? Are we going to be selling more SWUs or just charging more or what?

Answer 13. Estimate revenues for FY 1983 are $2,032,700,000. This is $202,500,000 more than the FY 1982 revenue projection. The additional revenue is attributable to government revenue sales of $109,000,000; a SWU price increase, and an increase in projected SWU sales up to 14 million total SWU from 13.9 million SWU.

Question 14. Why is DOE proposing to carry over some $65.654 million to FY 1984 rather than applying this amount to other activities within the enrichment program or using this to support other programs within the Department?

Answer 14. The $65 million surplus is a direct result of our cost reduction efforts. By keeping costs down, we will be better able to keep the SWU price competitive. Also, there will be years when a surplus occurs (such as in FY 1983), and years when a deficit occurs. By carrying the surpluses over, we hope to offset deficit budgets and minimize appropriation requirements in any one year.

Question 15. What are the projected charges for enrichment services during fiscal years (i) 1982, (ii) 1983, (iii) 1984, and (iv) 1985?

Answer 15. The charges for uranium enrichment services will be $130.75 per SWU under long-term Fixed-Commitment and Adjustable Fixed-Commitment contracts in FY 1982 and $138.65 per SWU in FY 1983. In constant FY 1983 dollars, the projected charges in FY 1984 and 1985 are $136.50 and $133.50 per SWU, respectively.

Question 16. What factors affect the projected charges for enrichment services?

Answer 16. The major factors which will affect the projected charges are changes in the Government's cost of money (i.e. interest rate), the power cost escalation rate, the general escalation rate, and changes in separative work demand.

Question 17. What portion of the current and projected charges are attributable to the cost of constructing the Portsmouth Gas Centrifuge Facility?

Answer 17.

| | Charge | GCEP Portion |
|---|---|---|
| FY 1982 | $130.75 | $13.80 |
| FY 1983 | 138.65 | 20.50 |
| FY 1984 | 136.50 | 23.00 |
| FY 1985 | 133.50 | 24.50 |

Question 18. What effect will payment from government customers have on the cost of enrichment services for commercial customers?

Answer 18. The full cost recovery pricing methodology is designed to assure that civilian customers do not pay the costs associated with the production of separative work for Government customers. Thus, payment from Government customers will not have any effect on the price or cost of enrichment services for commercial customers. However, actual receipt of revenues from Government customers will increase the amount of cost revenues available to offset the budgetary requests made for the enrichment program.

Question 19. What was the value of the enrichment services provided to government customers for each of the last five years?

Answer 19. The value of enrichment services provided to Government users at the selling prices in effect in the year of delivery are:

| Fiscal Year | Millions, $ |
|---|---|
| 1977 | 101.3 |
| 1978 | 94.3 |
| 1979 | 96.5 |
| 1980 | 79.7 |
| 1981 | 147.3 |

Question 20. What is the difference in the price of SWUs charged to government customers from the price charged commercial customers and what is the statutory basis for such a distinction?

Answer 20. The price of SWU's charged to Government customers is the same as that charged to commercial customers except that non-budgetary components (i.e., depreciation and interest costs) are excluded. This distinction, we believe, is consistent with the provisions of the Economy Act of 1932.

Question 21. On page 131 of Volume 4 of the Department of Energy Fiscal Year 1983 Congressional Budget Request Book it is stated that "Additionally, 1.2 million SWU is sold to government customers at a value of $109,000,000. $43,346,000 of this amount is credited against the Uranium Enrichment Program..." What is meant by "crediting" such sums "against the Uranium Enrichment Program?"

Answer 21. The word "crediting" is intended to describe the use of the revenues received from the Government user to offset $43,346,000, of the FY 1983 uranium enrichment total budget authority requirements.

Question 22. Given current knowledge of the Fiscal Year 1982 program, what are the projected revenues and program costs and how do such revenues compare with estimates made last year by (i) the Office of Management and Budget, and (ii) the Congressional Budget Office?

Answer 22. Currently, projected FY 1982 revenue estimates are $1.80 billion, and a full cost recovery pricing method is being utilized. Program costs are currently estimated at $1.77 billion. These projections are almost exactly the same as those made one year ago by the Department and the Office of Management and Budget.

In July of 1981, the Congressional Budget Office (CBO) estimated FY 1982 uranium enrichment revenues at $1.58 billion, assuming cost recovery pricing, and estimated that an additional $205 million could be received if fair value pricing were enacted. CBO's current FY 1982 revenue estimate is $1.75 billion.

Question 23. Withdrawals from the stockpile will be sold at a price equal to the current price for new production, resulting in a profit for each sale, consisting of the difference in the cost of production and the sale price. How are such profits accounted for in the Department's budget, and what are such funds used for?

Answer 23. The price of separative work recovers only the actual costs of providing enrichment services. In arriving at a selling price, the cost of the beginning stockpile is added to the cost of production for the next 10 years to arrive at an average price. Therefore, all separative work is sold at the same price whether the separative work comes from the stockpile or from current production. No "profit" is realized because the price is set to recover only costs. The costs of production from all sources are accurately recorded in the Uranium Enrichment Financial Statements.

The budget simply reflects the revenues received in any one year as an offset to that year's budget request.

Question 24. The fiscal year 1983 budget request includes for the first time estimates for revenues from sale to government customers. How were such services for government customers funded in the past, and where does such funding appear in prior budgets?

Answer 24. The funds required to produce enriched uranium for Government users prior to FY 1983 have been provided from the Uranium Enrichment Activities program budget. These budgets have included all of the funds needed to produce civilian and Government separative work requirements.

QUESTIONS 25 - 32

## URANIUM ENRICHMENT DEMAND CHARGES

Question 25. Has DOE considered asking TVA to offer a discount on this surplus electricity to make it attractive for a utility to offset oil or gas fueled power production? In this way, the DOE and TVA could be serving the national interest in lowering oil and gas consumption pursuant to the Powerplant and Industrial Fuel Use Act, and could be mitigating this 25% capacity charge. Theoretically, TVA could offer up to a 24% discount and still come out ahead.

Answer 25. To date, the question of price has not been a major consideration in TVA's attempts to offset oil- or gas-fired generating capacity. The biggest problem is access to the markets which utilize gas or oil. For example, Florida is heavily dependent upon oil-fired generating capacity. There is only a limited amount of transmission capacity into Florida, and this capacity is being fully utilized by the Southern Co. to sell its excess power. TVA would be price competitive in Florida but cannot gain access to the market. Also, TVA could sell power to the Southwest, to Texas, and to the Gulf states, if it had access to the market. However, Middle South Utilities and the Southern Co. are located between TVA and the potential market and can service this market. We are currently examining the entire region to see if there are markets where we could deliver the excess TVA power.

Question 26: Would DOE favor lifting the restriction in Section 44 of the Atomic Energy Act, which prohibits DOE from directly selling its excess contract electricity?

Answer 26: We have examined in detail the legislative history underlying Section 44 of the Atomic Energy Act and have concluded that there is no need to amend that provision. The purpose of Section 44 was to permit DOE's predecessor (the Atomic Energy Commission) to dispose of energy it produces in the course of its own operation, but to preclude it from entering the power-producing business in competition with private and/or Congressional authorization to construct or operate such commercial facilities. The restriction on the commercial sale of power by DOE (of power not produced incident to the operation of research and development or production facilities) was intended to apply only to power which is both produced and sold by DOE. Accordingly, since DOE did not generate the power which it has purchased under long-term contracts from utility suppliers for use in its enrichment plants, Section 44 of the Act does not prevent DOE from selling that power.

However, there are still several major constraints facing DOE in its attempts to sell its excess power. The first constraint is the terms of the DOE/TVA contracts. Section 15 of the contract states that DOE can only resell the power if agreement is given by TVA. Section 19 of the contract states that assignment of the contracts by DOE to another party is possible only if TVA agrees. If a market exists for the power, TVA prefers to serve that market, if possible, before allowing DOE to do so. The second major constraint facing DOE is that it does not own any transmission facilities. Any movement of the power would be done over TVA transmission facilities and would require the cooperation and assistance of TVA.

Question 27. Since TVA is restricted in considering the power needs of parts of the region beyond its legal ability to serve, should the Congress consider legislation to require a study of power needs and utility capacity in and around the Southeastern region of the United States?

Answer 27. A study of the power capability and needs of the Southeastern U.S. and how that region interacts with other parts of the country could be useful. It might identify previously unknown markets for excess power and it might also identify the steps which need to be taken in order to more efficiently utilize our power generating resources. Legal and technical barriers currently restrict the movement of excess power to areas which could use the power to meet the demand for electricity or to supplant more expensive sources of power. A regional or national solution to this problem could benefit the country. However, the Office of Uranium Enrichment and Assessment does not possess the expertise or the resources to accomplish such a study.

Question 28. What power budget level would be required to take the contract amounts of electricity and correspondingly, how much would the stockpile grow?

Answer 28. The contract demand for FY 1983 is 4,548 megawatt-years. In order to purchase all of this power, a cascade power budget of $1,298 million would be required. The incremental production associated with purchasing the contract demand is 7.1 million SWU. Based on the FY 1983 budget, the stockpile would be reduced by 5.5 million SWU. The incremental production would more than offset this anticipated reduction and would increase the stockpile by 1.6 million SWU.

Question 29. If the contract amount of electricity is taken, how much extra would have to be appropriated to cover the power costs?

Answer 29. Purchasing the contract demand in FY 1983 would increase the power budget by $394 million, from $904 million to $1,298 million.

Question 30. Have you asked TVA to look into various options, for example, wheeling the power, through a utility to whom TVA may sell power, to other government-funded complexes such as the Princeton Plasma Physics Lab, Brookhaven, Fermi Lab, etc.?

Answer 30. We are currently studying the possible arrangements for wheeling surplus DOE contract capacity to DOE installations in areas outside of the TVA service areas. However, the wheeling of TVA power to another Government facility is often not possible because transmission capacity to move the power may not be available, another utility situated between TVA and the facility can supply the power, or the utility which would normally serve the facility may have sufficient capacity to continue to serve the facility at a lower delivered cost.

Question 31. In view of the past success DOE has had in obtaining capacity charge relief from OVEC, what probability do you think the Department has in obtaining relief of the $22 million in demand charges anticipated for FY 1983? When does DOE expect to receive OVEC's decision regarding these charges?

Answer 31. At this time, the prospect of obtaining relief from the $22 million in capacity charges for power not purchased is not good. OVEC is receiving heavy criticism from the State of Ohio concerning its previous agreements with DOE which reduced our contract demand. The State of Ohio generally feels that OVEC would have gained access to the power without granting relief to DOE and, therefore, the other power users in Ohio are subsidizing DOE. We do not expect to receive a decision from OVEC before June 1982.

Question 32. Will DOE's current negotiations with its power suppliers limit DOE's ability to get the power needed for its diffusion plants after 1989, should GCEP not be built as planned?

Answer 32. No, the current negotiations will not adversely impact DOE's ability to obtain power in the 1990's. The current negotiations deal with modifications to the current contracts with our power suppliers. These contracts expire in the early 1990's and new contracts will have to be negotiated to assure delivery of power in the 1990's. However, negotiations with TVA and EEI will have to be completed by the end of 1982. Any modifications to the GCEP schedule must be known prior to this in order for DOE to contract for guaranteed power deliveries in the 1990's.

QUESTIONS 33 - 41

# ADVANCED GAS CENTRIFUGE (AGC) TECHNOLOGY

Question 33. Please describe in greater detail what you are trying to accomplish in the AGC Program.

Answer 33. The purpose of the AGC program is to develop gas centrifuges of increased separative capacity which can reduce separative work costs when used in a gas centrifuge enrichment plant. The capacity increases are being accomplished by increasing the peripheral velocity of the active rotating element (the rotor) and by improving the gas flow within the rotor. Simplification of the mechanical design is being pursued to reduce the initial cost of the machine and to improve its reliability.

Question 34. What are the objectives of the AGC Program for the Set IV, Set V, and Set VI, developments?

Answer 34. Centrifuge improvements proceed in discrete generations. A generation of a centrifuge is called a "set." The advanced centrifuge program is presently developing the Set IV machine, some planning has proceeded with the Set V machine, and the Set VI machine has had a small amount of planning completed. The objective of these machines are:

Set IV - a 50 percent separative capacity increase over the machine initially going to the enrichment plant. It is planned to be available by 1988.

Set V - a 75 percent separative capacity increase over the machine initially going into the enrichment plant. It is planned to be available by 1993.

Set VI - a 100 percent separative capacity increase over the machine initially going into the enrichment plant. It is planned to be available by 1998.

Question 35. What is the plan and schedule for deploying Set IV centrifuges?

Answer 35. The Set IV centrifuges will be installed in all buildings of the centrifuge plant starting in 1988 with building 3. The Set IV machine will also be retrofitted into the earlier buildings of the enrichment plant as the initial complement of machines fail.

| | |
|---|---|
| Question 36. | What are the anticipated accomplishments in FY 1982 and FY 1983 for the AGC Program? |
| Answer 36. | The expected primary accomplishments of the Set IV development program are as follows: |

a. FY 1982

- Demonstrate a separative capacity increase of 30 to 35 percent over the initial plant machine in development test machines.
- Operate about 10 different machines at the higher speed expected of this design.
- Complete the prototype design of the machine assemblies.

b. FY 1983

- Select the proven specific concepts which will be used in the Set IV machine.
- Continue verification testing and optimization, at the sub-assembly level, of the concepts selected.
- Operate 5 integrated full-sized machines of the selected design to check potential areas of weakness and low reliability.
- Demonstrate a separative capacity increase of 50 percent over the initial plant machine in development test machines.

Question 37. What are the details of the funding requested in FY 1983 for the gas centrifuge process development and demonstration program?

Answer 37. The FY 1983 gas centrifuge process development and demonstration program funding consists of:

| | |
|---|---|
| Basic Studies | $ 3,740,000 |
| Materials | 1,750,000 |
| Advanced Centrifuge Dev. | 27,220,000 |
| Facility Operations | 29,841,000 |
| Support & Special Studies | 6,949,000 |
| Total | 69,500,000 |

Basic Studies are a continuation of scientific expertise and experimental facilities for the theoretical modeling and experimental investigation of centrifuge stability and flow efficiency improvement.

Materials efforts include the evaluation of the compatibility and life of centrifuge components in a $UF_6$ environment, the search for new higher strength low density materials, and testing of proposed materials and material geometries.

Advanced Centrifuge Development - defined in more detail in previous questions (33 through 36).

Facility Operations. The operation and maintenance of the base facilities required to support the development of the advanced centrifuge, the operational testing of GCEP prototypes, and the recycle and assembly of both GCEP prototype and advanced centrifuges.

Support and Special Studies. The management and administrative (planning and budgetary) activities to support the above major budget categories, and the performance of specialized tasks such as failure investigations, quality assurance, and safety.

Question 38. What is the GCEP Centrifuge Design Verification Schedule?

Answer 38. The GCEP Centrifuge Design has already passed a formal Qualification program. Long term reliability data are being accumulated in several test facilities.

Question 39. What is the basis for the stated 50 percent improvement of advanced technology centrifuge over the baseline centrifuge?

Answer 39. The 50 percent separative capacity improvement is based upon two basic growth areas:

a. The speed of the rotor has improved potential which can be realized through the greater understanding of rotor dynamics and the structural response of key components.

b. Theoretical studies of proven predictive accuracy have indicated that alternate techniques of directing the gas flow within the centrifuge rotor can increase the separative efficiency of the machine. The hardware items to afford this redirection are being developed and their tests in full sized machines are imminent.

Question 40. What is the total estimated cost for the development for each of the Set III, Set IV, Set V, and Set VI centrifuges?

Answer 40. The Set III program is the culmination of over 20 years of centrifuge development. Its costs through FY 1982 (all previously accumulated development costs) were approxiamtely $664,000,000. The expected cost of the Set IV development program is estimated to be approximately $125,000,000 in FY 1984 dollars. This program began in FY 1982 and is planned to end in FY 1988. Advanced material work that would support a Set V concept is planned to begin in FY 1984. Should Set V be authorized, its total cost is estimated to be approximately $175,000,000. Due to the distant start of the Set VI program, no cost estimates have been made for it.

Question 41. What portion of the cost of producing a SWU is attributable to the cost to date of developing centrifuge technology?

Answer 41. The $138.65 SWU price issued on February 22, 1982, and effective August 21, 1982, contains $2.68 for costs attributable to developing centrifuge technology.

QUESTIONS 42 - 48

## ADVANCED ISOTOPE SEPARATION (AIS)

Question 42. What is the Process Evaluation Board's schedule for selection of one of the AIS processes?

Answer 42. On April 21, 1982, the Process Evaluation Board (PEB) presented its recommendations for AIS process selection to the Under Secretary. The Department has evaluated the PEB's recommendation and announced process selection on April 30, 1982.

Question 43. What methodology is the PEB using to make such a selection?

Answer 43. To provide a basis for selection, criteria were developed by the AIS Program Office with assistance provided by staff of the laboratories participating in the AIS program. These criteria were issued on August 13, 1981.

Using this document as a basis, the PEB focused on answering the following questions:

- What are the prospects for successful engineering development?
- Is the technical base adequate to proceed to the next step in process scale-up?
- Do the projected economics of the technology meet the AIS program goals?
- Is there sufficient flexibility within the technology and in the design of large facilities sufficient to overcome potential problems?
- Does the proposed Development Module provide adequate confidence that will enable DOE to commit to the deployment of the technology?
- Are the program plans, schedules, and costs realistic?

The PEB conducted its assessment by visits to the various participating laboratories and by requiring the participants to submit detailed information concerning such things as the fundamentals of the process, preconceptual design reports, economic assessments, etc. A vital ingredient of the process selection was a "Peer Review" in which each participant critiqued the other two processes in an open forum. Such a technical exchange provided in-depth reviews of the scientific and engineering status of each program using adversary procedures.

The PEB established a framework within which it assessed the four major evaluation categories. The following is a description of this framework:

1. Performance Risk
    - Evaluation of the status of the experimental program and where major uncertainties still exist.

- Evaluation will be relative to proposed plant and development module designs.
- Process science models exist which have been benchmarked to the degree necessary to reasonably predict scaling relationships.
- Impacts of uncertainties were evaluated by varying the parameters used in the economic assessments.

## 2. Engineering Design

The basis for the evaluation was the completeness and depth of engineering design.

## 3. Economic Benefits Evaluation

The role of the PEB in the Economic Benefits section was to place reasonable bounds on (1) the future development cost of the AIS program, (2) the projected AIS SWU costs, and (3) the technology deployment date.

## 4. Technology Development Plan

In this category the PEB evaluated the:

- program plans
- management teams
- engineering and development costs
- program schedules
- flexibility of the process to meet varying product assays
- development of an industrial vendor base

Question 44. Would a delay in choosing one AIS technology delay the deployment of a future full-scale production plant?

Answer 44. Yes. The estimated AIS deployment date assumes the successful completion of an engineering development program to eliminate process uncertainties associated with hardware scale-up. A delay in selecting an AIS technology for engineering development would constrain the entire program to the basic R&D and small scale demonstration phase,unless there is a significant increase in the funding for the program.. Technical uncertainties can no longer be adequately addressed at this scale of hardware or at this level of equipment integration.

| | |
|---|---|
| Question 45. | What is the schedule for the engineering development of the selected AIS Process? |
| Answer 45. | The engineering development phase of AIS would conclude with the operation of a Development Module (DM) by the late 1980's. The DM's main objective is to resolve any remaining process physics or subsystems integration performance issues at full plant scale. |

Question 46. What additional developmental stages will the AIS program have to complete before the selection of an AIS technology could be made on the basis of full production costs?

Answer 46. The Development Module (DM) for the selected Atomic Vapor Laser Isotope Separation (AVLIS) process will be a full plant module with an estimated separative capacity of 1 Million SWU. Therefore, both capital cost and operating cost estimates for the full production plant can be benchmarked after the operation of the DM. By 1990, the Department expects to choose between the advanced gas centrifuge and advanced isotope separation technologies for possible replacement of existing gaseous diffusion plants and for providing new enrichment capacity.

Question 47. What will be the cost of the engineering development of the chosen process?

Answer 47. The total AIS program costs from FY 1983 thru FY 1989 would be about $600 M. Of that amount, nearly $180 M would be for the design, engineering and construction of the development module. The remainder would be allocated primarily to process R&D, subsystem scaling, performance and verification.

Question 48. What would be the cost of delaying the AIS selection date and funding the additional work needed to increase confidence that the chosen AIS technology will be the most economically viable one?

Answer 48. The AIS program is in the basic R&D and small scale demonstration phase. The nominal incremental cost of keeping the three AIS technologies funded through FY 1983 would be bout $55 M. However, additional funding would be anticipated in FY 1983 to complete designs and initiate procurements of the next generation of process specific equipment to address the remaining technical uncertainties for each technology.

Based on the PEB's analyses, we believe sufficient information is available on each AIS technology to select a single process to proceed into the engineering development phase at this time. Any additional information generated from existing hardware would not be able to reduce the presently acceptable risks identified with process selection now.

QUESTIONS 49 - 51

# PRIVATIZATION OF THE URANIUM ENRICHMENT PROGRAM

Question 49. What is the status of the consideration of the "privatization" of the Uranium Enrichment Program?

Answer 49. A study of the feasibility of turning uranium enrichment operations over to the private sector is only at the very preliminary stage at this time.

Question 50. What role, if any, has the private sector played in these considerations?

Answer 50. There has been no input from the private sector in the considerations up to this point. It is our intention to seek the views of private industry before any final recommendations are made.

Question 51. What expressions of interest have been made by the private sector in regard to assuming the responsibility for providing such service?

Answer 51. There has been no formal expression of interest from the private sector. It is our intention to seek the views of private industry before any final recommendations are made.

QUESTIONS 52 - 60

# U.S. INVOLVEMENT IN THE PROPOSED AUSTRALIAN URANIUM ENRICHMENT FACILITY

Question 52. What is the present status of efforts to assist private enterprise in the United States to obtain the proposed contract for the Australian uranium enrichment facility?

Answer 52. U.S. companies having detailed access to classified centrifuge enrichment technology have been briefed with respect to our knowledge of the plans of Australia to evaluate, and possibly construct, a commercial uranium enrichment facility with the assistance of a non-Australian holder of enrichment technology, and the fact that three non-U.S. holders of enrichment technology have been actively competing to be selected as Australia's partner. Companies have been advised that only unclassified information currently can be used in any company discussions with the commercial entity conducting the feasbility evaluations. It is our understanding that several U.S. companies have been in touch with the Uranium Enrichment Groups of Australia (UEGA). Companies have also been advised that any proposals to UEGA would require security clearance by the Department of Energy. Further, information on the status of proposed U.S. involvement in the UEGA program is contained in responses to questions 53-60.

Question 53. What, if any, legal steps must be taken to make the enrichment technology available to the private sector in order for domestic firms to compete for the proposed Australian facility?

Answer 53. U.S. Government-owned enrichment technology would be involved if the United States, through U.S. private firms, were selected by Australia as its partner in the evaluation and possible construction of a uranium enrichment facility. France, Japan, and Urenco (a consortium of the United Kingdom, West Germany, and The Netherlands) are also seeking to be selected as Australia's partner. A new or amended Agreement for Cooperation between the U.S. and Australia would be required before any classified information could be made available by U.S. firms. Such an Agreement would have to assure that U.S.-owned technology would be protected as well in Australia as in the U.S. and is not accessible to third parties. The Agreement would be subject to statutory review by the U.S. Congress before becoming effective. Should the U.S. be selected by Australia as its partner, and an implementing Agreement negotiated between the U.S. and Australian Governments and accepted by Congress, the U.S. private companies involved would be authorized to license the use of the technology for the evaluation and possible construction of an enrichment facility. The technology would not be sold. A substantial royalty would be received by the U.S. Government, recognizing the value of the technology.

Question 54. What, if any, legal steps must be taken in order for domestic firms to offer for sale to Australia the uranium enrichment technology.

Answer 54. U.S. Government-owned enrichment technology would be involved if the United States, through U.S. private firms, were selected by Australia as its partner in the evaluation and possible construction of a uranium enrichment facility. France, Japan, and Urenco (a consortium of the United Kingdom, West Germany, and The Netherlands) are also seeking to be selected as Australia's partner. A new or amended Agreement for Cooperation between the U.S. and Australia would be required before any classified information could be made available by U.S. firms. Such an Agreement would have to assure that U.S.-owned technology would be protected as well in Australia as in the U.S. and is not accessible to third parties. The Agreement would be subject to statutory review by the U.S. Congress before becoming effective. Should the U.S. be selected by Australia as its partner, and an implementing Agreement negotiated between the U.S. and Australian Governments and accepted by Congress, the U.S. private companies involved would be authorized to license the use of the technology for the evaluation and possible construction of an enrichment facility. The technology would not be sold. A substantial royalty would be received by the U.S. Government, recognizing the value of the technology.

Question 55. What assistance does the Administration propose to provide domestic firms in order to support their efforts to obtain this contract?

Answer 55. Since it is believed in the National interest that the U.S. rather than another enrichment supplier be the Australian partner, the Administration proposes to make its enrichment expertise available to U.S. companies, on a cost basis, to the extent that its own program is not negatively impacted. The Administration would also be prepared to make SWU's available to U.S. companies (on a basis which recovers all U.S. costs for such a program) to permit them to offer certain backup assurances to Australia in the event anticipated production from an Australian facility is not achieved.

Question 56. What is the relationship between the Administration's interest in promoting American participation in the proposed Australian uranium enrichment plant and the present consideration of transferring the domestic uranium enrichment program to the private sector?

Answer 56. The Administration's interest in promoting American participation in the proposed Australian enrichment venture, in lieu of that of another enrichment supplier, is primarily due to the substantial net commercial and political benefits that we believe would accrue to the U.S. While not directly related to the matter of consideration of transfer of responsibility for domestic uranium enrichment to the U.S. private sector, the involvement of U.S. companies in Australia may expose them to commercial enrichment activities in a way which ultimately could assist domestic commercialization.

Question 57. What is the relationship between the Administration's interest in promoting American participation in the proposed Australian uranium enrichment plant and the Administration's plan for (i) continued funding of the Portsmouth gas centrifuge plant, and (ii) continued operation of the existing uranium enrichment facilities?

Answer 57. All Administration's studies and evaluations with respect to prospective involvement in an Australian project have been based upon estimates of the need for new enrichment capacity to meet free world needs in the 1990's and beyond, assuming completion of the full Portsmouth Gas Centrifuge Enrichment Plant (GCEP). We believe that GCEP is necessary to meet, on an economical basis, our projections of the share of the uranium enrichment market to be served by U.S. capacity. GCEP also provides the opportunity to displace costly gaseous diffusion production and, thus, improve the United States' competitive position in the international marketplace by keeping enrichment prices as low as possible. Accordingly, (i) continued funding of GCEP would not be affected and (ii) existing gaseous diffusion facilities would continue to operate until their production was no longer needed to meet U.S. enrichment supply requirements. We currently predict that some diffusion capacity is likely to be needed until well after the turn of the century, although the rate at which replacement capacity can be provided and the magnitude of future U.S. enrichment contract obligations will be key factors in determining this point.

Question 58. What is the estimated impact of the entry of an Australian uranium enrichment program into the world market on the estimated demand for United States enrichment services, and what is the basis for such estimates?

Answer 58. It is difficult to predict the impact of the entry of an Australian uranium enrichment program into the world market on estimated demand for U.S. enriching services. This will probably depend, to some extent at least, upon the character and timing of the project, and its pricing and contracting policies. These will be developed during the detailed feasibility evaluation phase which is to be conducted in association with the selected technology supplier and assumes that a decision to proceed is made by the Uranium Enrichment Group of Australia (UEGA) as a result of that evaluation. The project is presently conceived to be rather modest in size, beginning at a low capacity of several million separative work units per year by about 2000. There appears likely to be sufficient uncommitted new enrichment business available in this period (from outside the U.S. and in addition to the foreign new business which has been projected to come to the U.S.) to easily support such a project. It is, of course, possible that some foreign supply contracts now held by the U.S. could be terminated by the customers, in spite of termination penalties, in favor of any non-U.S. supplier, as has occurred in the past, but it is difficult to predict any such specific actions. In any event, the U.S. intends to compete vigorously in the world enrichment services market.

Question 59. Is the Administration engaged in any government-to-government discussions of any type with Australia regarding the potential availability of the uranium enrichment technology, and if so, could you summarize such discussions?

Answer 59. The Administration is not engaged in any government-to-government discussions with Australia regarding the potential availability of U.S. uranium enrichment technology. We had previously notified Australia that the U.S. was prepared to make its technology available for detailed evaluation of the feasibility of an enrichment project and use in such a project if feasibility is confirmed. We noted that implementation of this position would be subject to conclusion of satisfactory intergovernmental arrangements assuring protection of the technology, and covering nonproliferation and safeguards matters, in addition to conclusion of mutually acceptable commercial arrangements between the Uranium Enrichment Group of Australia (UEGA) and U.S. companies involved. We suggested early discussions on an implementing Agreement for Cooperation. However, the Government of Australia apparently wishes to await selection by UEGA of its preferred partner before undertaking government-to-government discussions with the successful partner nation.

Question 60. One of the major factors in awarding the Australian contract is reported to be the degree of assurance which can be provided that a market for such enriched uranium exist. What proposals are the Administration prepared to make to assure the availability of a market?

Answer 60 The Administration does not believe that it should seek to pressure enrichment customers to deal with any particular supplier; it believes that customers will make their choices, on the basis of a comparison of services offered, and their own self-interest, from the several available suppliers.

QUESTIONS 61 - 75

# POTENTIAL PARTICIPATION OF MEXICO IN GCEP AND FOREIGN ENRICHMENT SALES

| | |
|---|---|
| Question 61. | To what extent is it true that Mexico might become a partner in GCEP? |
| Answer 61. | Our discussions with the Mexican Government officials to date have covered in a general way the status of our civilian nuclear power programs. It is our hope that they will purchase U.S. reactor equipment and enrichment services. Since the evaluation of the reactor proposals which Mexico has received is incomplete, no consideration has thus far been given to enriched uranium supply. Therefore, it cannot now be said that Mexico might become a partner in GCEP. |

Question 62. Why couldn't Mexico obtain enrichment services from the U.S. even if it wasn't a partner in GCEP?

Answer 62. Mexico can obtain enrichment services from the U.S. without being a partner in GCEP -- as they are presently doing for Laguna Verde units #1 and 2.

Question 63. What currently prevents the U.S. from "packaging" uranium enrichment services into a transaction which includes uranium enrichment services, a reactor, raw material, financing, and so on?

Answer 63. Proposals for reactors, raw materials, and engineering services to potential foreign customers are the responsibility of U.S. industry and we believe this arrangement cannot, and should not, be materially altered by U.S. Government involvement. However, the U.S. Government does have a role and an interest in foreign nuclear project financing, the sale of enrichment services, issuance of export licenses, etc. If properly done, e.g., with regard to the needs and interests of U.S. industry and the foreign customer, "packaging" can have a benefical impact on the U.S. prospects for the sale of reactors, equipment, and enrichment services. "Packaging" in the manner just described is what we are attempting to accomplish in Mexico, and in other countries where we perceive there are market opportunities for reactor and separative work sales.

Question 64. To what extent does the inability to provide such a nuclear power package deal restrain U.S. sales of U.S. enrichment services?

Answer 64. We believe that an increasingly strong synergistic relationship is evident between the sale of U.S. reactors and the sale of U.S. enrichment services, and this is the motivation for efforts we are exerting in Mexico and elsewhere as described in the answer to question #63.

Question 65. Does DOE plan to facilitate the "packaging" of enrichment services along with other related fuel cycle services to meet the needs of the marketplace and if so, how does it plan to proceed?

Answer 65. Our ability to package enrichment services with other fuel cycle services, such as reprocessing, will depend on the technical, financial, and institutional status of these other related fuel cycle services. Our efforts to revitalize nuclear fuel reprocessing are not yet complete, and until this is completed, we are unable to describe just how we would proceed in this regard.

Question 66. What are the prospects for increasing foreign sales? What are the factors that inhibit expanded sales?

Answer 66. With the current low-volume market for new enrichment sales world-wide, the oversupply of enrichment capacity and the aggressive competition among suppliers, it is difficult for DOE to increase its share of the foreign market. New near-term markets include Egypt, Taiwan and Mexico, with subsequent possibilities in Yugoslavia and elsewhere. We are presently negotiating with Egypt to sign three new DOE contracts of 1000 MWe each and to increase its existing DOE contract by 300 MWe, amounting to 3300 MWe of new sales. Taiwan's 2000 MWe of planned nuclear power capacity are open to competition and proposals are now being evaluated for Mexico's 1800-2600 MWe of planned capacity.

The factors that inhibit expanded sales are:

- low-volume market
- tough competition (price, flexibilities)
- oversupply of enrichment capacity
- national goals and policies of foreign buyers
- U.S. political posture -- re: nonproliferation
- desire for assurance of supply (includes diversification)
- difficulty in arranging attractive financing
- DOE's inability to offer special concessions to prospective buyers.

Question 67. How many foreign contracts for enrichment services were signed in FY 1981, and how many contracts with foreign users were expected to be signed in FY 1982 and FY 1983? Please specify (1) the type of contract involved, and (2) the amount of separative work involved?

Answer 67. One enrichment contract with a foreign user was signed in FY 1981. This contract was a short-term, fixed-commitment contract, for a 5-year term, with the United Kingdom. The amount of separative work involved is classified.

During FY 1982, no contracts have been signed to date. There is a possibility that one or more contracts may be signed this year with Egypt, and one contract with a European utility. The contracts would be Adjustable, Fixed-Commitment (AFC) contracts covering the enrichment service needs for those reactors over a period of 30-years. The quantity of separative work involved is expected to be in excess of one million SWUs for the European utility while the amont for Egypt is still under negotiation.

During FY 1983, DOE may sign contracts for one or two large reactors with Mexico and perhaps two with Taiwan. Other suppliers are also competing for these contracts.

Question 68. The December 2, 1980 report entitled Uranium Enrichment Management Review recommended "that DOE should immediately consider the following:

a) Take more aggressive steps to renegotiate contracts for the electric power needed to run the diffusion plants;

b) Conduct a more formally organized and rigorous investigation of the minimum level of operating the diffusion plants;

c) Confirm a full commitment to complete the first two buildings of the gas centrifuge project as fast as economically practicable;

d) Give the enrichment enterprise control over the management of the advanced isotope separation research and development program;

e) Support legislation to establish a revolving fund;

f) Evaluate the practicality of establishing the enrichment enterprise as an independent agency similar to the Tennessee Valley Authority (TVA)."

It was further recommended "that the following steps be taken by the Office of Uranium Resources and Enrichment (OURE):

a) Press for negotiation of a project stabilization agreement for the Portsmouth centrifuge construction project to diminish the possibility of jurisdictional and other labor union disputes;

b) Update its strategy on an annual basis;

c) Develop a model for use in long-range strategic planning and policy studies;

d) Evaluate a probabilistic method of forecasting enrichment demand;

e) Devote more resources to planning and marketing activities;

f) Reassess cancellation charge policies to eliminate the current situation that promotes cancellation of its own rather than competitors' contracts due to low DOE charges;

g) Supplement its auditing procedures by engaging outside auditors to lend added credibility to the enrichment enterprise;

h) Develop a set of overall objectives jointly with higher management;

i) Clarify the information needs of higher levels of management."

What has DOE done with regard to the implementation of these recommendations?

Answer 68. A number of actions have been taken to implement the recommendations of the review team.

Regarding power to the diffusion plants, with the exception of TVA in FY 1981 and 1982, the DOE has been able to reduce contract power deliveries under letter agreements and contract modifications with the suppliers. The reductions have been adequate to relieve DOE from all capacity charges for power not purchased for negotiated EEI and OVEC reductions in FY 1981 through 1989, and from a portion of the capacity charges for power not purchased from TVA in FY 1981. DOE has been successful in eliminating $492 million in capacity charges. Negotiations with TVA have not been totally successful and, consequently, DOE paid $27 million to TVA in capacity charges for power not purchased in FY 1981. The estimated capacity charges to TVA in FY 1982 for power not purchased are $111 million.

In December 1980, a program was instituted to assess the minimum acceptable risk power level for the gaseous diffusion complex. Interim technical reports were issued in March and September 1981. A final report will be issued in June 1982. At that time the operating contractors will make their recommendations as to what the minimum power level should be in light of the experience gained to date. A periodic update of the report will take place in the future as needed.

With respect to the Gas Centrifuge Enrichment Plant (GCEP), completion of the first two GCEP buildings as quickly as possible is the current project schedule and the focus of the current program effort. Funding for this purpose has been included in the President's budget. Efforts to negotiate a GCEP project labor agreement were unsuccessful and were abandoned, and our project experience to date suggests that such an agreement on the GCEP project is neither necessary or desirable.

The recommendation to integrate all enrichment activities within the enrichment enterprise was implemented during the second quarter of FY 1981 when the Advanced Isotope Separation (AIS) program was placed under the management responsibility of the Office of Uranium Enrichment and Assessment.

The Administration continues to support efforts to operate the enrichment enterprise in a business-like fashion. The Administration is currently exploring the possibility of private sector involvement in the enrichment business as the most direct way of achieving this objective.

All of the recommendations regarding improvements to the Department's enrichment planning efforts have been or are being implemented. However, no additional staff positions have been obtained for planning and marketing activities because of manpower restrictions within the Department. Rather, we are intensifying activities within the limits of available manpower.

Reassessment of the Department's contract cancellation policies confirmed that termination charges in competitor contracts are comparable to DOE's. There is no evidence that customers are terminating DOE contracts because DOE's termination charges are low. On the contrary, DOE customers have complained that our termination provisions are too restrictive.

Finally, the Office of Uranium Enrichment and Assessment has initiated a procurement action to engage an outside auditor as recommended by the review team. This request is currently under consideration within the Department.

Question 69. What are the internal audit procedures and techniques used to estimate and control expenditures.

Answer 69. The procedures to estimate and control expenditures encompass a multi-system of checks and balances that begins with the preparation of budget requirements and ends with specific management cost control reporting. Based on instructions and assumptions provided by DOE, the contractor prepares and submits an annual budget estimate. This estimate proceeds through several critical reviews at the field office and DOE Headquarters level before a final budget is submitted to Congress. Expenditures are reviewed in a number of internal audits of expenditures once budget levels have been approved. Examples of specific internal audits include: Contract and Procurement, Warehousing and Inventory Control, Management of Capital Assets, Personnel Payroll, Cash Controls, and Travel, etc. In addition to the large number of formal internal audits conducted at the field level, OUEA performs management control of expenditures by requiring a series of cost control and variance reports to be sent to the Headquarters program manager on a periodic basis.

Question 70. How does the Office of Uranium Enrichment and Assessment use computer models in its decision making?

Answer 70. The Office of Uranium Enrichment and Assessment (OUEA) uses several computer programs as input to its decision making. An enriched uranium demand model and an enrichment complex production simulator model are used in preparing operating plans that are used in the development of alternative budget strategies.

A financial model is used to develop prices, discounted cash flows, and net cash requirements for alternative operating plans. Since the Uranium Enrichment Program is on a cost-recovery basis, minimizing the charge in the short and long run has been established as a criterion for the evaluation of operating strategies. Also, the ability of the program to pay its own way and operate in a positive cash flow as long as possible is another criterion. The model provides the necessary output to compare the alternatives against the established criteria.

An optimizing economic model of the enriched uranium industry is also used to a limited extent to identify methods of meeting demand based on minimizing combined customer and DOE costs for varying sets of assumptions. The resulting outputs thus provide some cost trends which are helpful for identifying decisions which are reasonably economically optimum.

Question 71. How are the models validated, and by whom?

Answer 71. Enriched Uranium Demand

The enriched uranium demand model is used to determine future annual demands for enriched uranium. The principal inputs are fuel cycle characteristics for various reactor types and refueling intervals, historical lead times, capacity factor, empirical constraints because of contract flexibility limitations, and projected gigawatt growth by reactor type and expected operating mode. The model has not been validated. It is a very simple model and its validity is totally dependent upon the assumptions therein. As noted above, the bulk of the assumptions reflect the experience to date and the current thinking of utilities and vendors. The error band in these assumptions is relatively small compared to the uncertainty in nuclear power projections. We also have had a consultant developing independently a more sophisticated and comprehensive SWU projection system. This effort is scheduled to be completed shortly. These two separate models should serve as a means of validation, one for the other.

An input to this model is a computer MWe growth file generated in a program/database which stores, retrieves, and summarizes data concerning the status of nuclear power reactors. Validation for this model is somewhat inappropriate as it is simply a manipulator of data. It has been checked and shown to be mathematically precise.

Uranium Enrichment Activity (UEA) Simulator

Given annual enrichment complex separative production civilian and government demands, feed availabilities, and other parameters, the model computes and reports feed and separative work balances (including feed purchases and new plant separative work if required) around the Uranium Enrichment Activity (UEA) complex. The model also reports the schedule of feed usage on a yearly basis and the feed and separative work contents of the demands and product inventories for both transaction and operating tails assays as well as any specified evaluation tails assay.

The model uses the standard equations for separation of the binary mixture, U-235 and U-238, in doing the computations. The model is primarily used to examine different scenarios utilizing alternative mixes in the use of natural uranium and low-enriched uranium inventories, power to the gaseous diffusion complex, availability of gas centrifuge capacity, etc. The combination of input and output of the model serve to define all the parameters of an operating plan.

The model has not been validated; however, it is very simple and its validity is dependent on the standard equations for separation of the binary mixture, U-235 and U-238, in doing the computations. These equations were developed during the 1940s and since that time have been extensively used by both government and industry. Furthermore, similar models have been used by other groups giving, for common assumptions, virtually identical results.

## Financial Model

The Office of Uranium Enrichment and Assessment (OUEA) has developed a financial model to (1) arrive at the charge for enrichment services, (2) prepare schedules for cash flow, (3) measure the short- and long-term impact on the cost of production and selling price of proposed actions, and (4) compare DOE price projections with our competition.

The financial model takes input financial and production data and generates the additional data needed to arrive at prices and schedules of cash flow. The model produces imputed interest costs, income statements, cost of goods sold, depreciation schedules, and advanced payment schedules that are needed to arrive at annual price projection. The extensive financial output is required because of the cost recovery pricing methodology. The financial data calculated for one year provide the beginning balances for the succeeding year's charge.

The model has not been validated. However, the model is based on the pricing methodology and financial system that has been consistently utilized since the beginning of toll enriching and that has been reviewed and approved by GAO. The GAO reviewed and approved the systems in the early 1970s and has periodically made spot checks.

## EDIC Model

The EDIC model is a model in place at Union Carbide in Oak Ridge. Although once used extensively, it is now used relatively infrequently. It is designed to simulate the enrichment complex, with suitable economic criteria incorporated so that it will develop economically optimum modes of operation with various optional input constraints. Through a series of sensitivity analyses over a plausible range of input assumptions, trends can be identified which are useful in decision-making. The model is not designed to provide absolute results. The model was used in the October 1980 strategy study to identify the sensitivity of AIS introduction dates cr overall enrichment economics. The model derives the name EDIC from its optimizing criterion: equal discounted incremental costs. The EDIC criterion as given above is a simplified statement of the basic criteria for economic optimization. Two basic criteria are involved:

1. Optimal Activity Level: The scale of an activity should, if possible, be expanded so long as its marginal net yield (taking into account both benefits and costs) is a positive value; and the activity should, therefore, be carried to a point where this marginal net yield is zero.

2. Relative Activity Level: For optimal results, activities should, wherever possible, be carried to levels where all yield the same marginal returns per unit of effort (cost).

These criteria, taken together with the fact that the cost of money is one of the relevant costs, lead to the more simply stated EDIC criterion. The objective, under the EDIC criterion, is to obtain minimum-cost enriched uranium taking into account the costs of both feed and separative work. Specifically, the objective is to minimize the present value of the combined controllable costs of DOE and its toll enrichment customers, referred to as the Total Enterprise Cost (TEC). The principal tradeoffs to which the EDFIC criterion applies are feed versus separative work, and production versus time. Thus the marginal cost relationships to which the optimizing criterion applies are specifically derived for the variables of uranium enrichment.

Inputs to the EDIC model include cost and performance data on existing and new plants, tails assay levels, cost escalators, and various special constraints. Output of the model includes a summary of operating plan parameters (power levels, tails assays, feeds, etc.), costs by category, total annual costs, and costs of the total campaign.

The model was thoroughly reviewed in the late 1960s by several organizations. An AEC planning and analysis group independently reviewed and verified the model. Another AEC group developed a general nonlinear optimization model which used a totally different mathematical procedure which provided almost a near duplication of the EDIC outputs. The EDIC model also was generally accepted by the technical community at that time as well as by the Congress and Bureau of the Budget (now Office of Management and Budget). More recently the Energy Information Administration (EIA) made a cursory review of the model structure and operation and determined both to be sound. GAO also very recently reviewed the model but we have not yet been advised of their findings.

Question 72. What has prior validation experience shown? Has it proven models to be accurate or inaccurate? Can you cite specific examples?

Answer 72. With respect to the enriched demand model, its validity is totally dependent upon the fuel cycle and lead time assumptions contained therein. As noted in a previous answer, the bulk of the assumptions reflect the experience to date and the current thinking of utilities and vendors. All in all, the model appears to give reasonable results over the long term when compared to other projections using common reactor schedules.

The Uranium Enrichment Activities Simulator is mathematically precise. It was developed during 1973 and since then has been used by several clients other than OUEA. Minor problems have been found in the model, basically in the way the beginning inventory of enriched uranium was handled by the model if the inventory was at an enrichment level other than that specified to be made by the model. This problem was rectified by adjusting the input beginning inventory to be consistent with the input assay for enriched uranium to be pre-produced by the model. Several other minor problems were found that were fixed. The model has been updated several times to fix both minor problems and to add additional input and output features.

The financial model is unique to the uranium enrichment program. However, the results to date show the model to be accurate based on past trends and non-model analysis.

The EDIC model is considered to give accurate results. One source testifying to the validity of the EDIC economic optimization procedure is the duplication of EDIC results in the late 1960s and early 1970s by a separate and totally different model. That model developed by the Atomic Energy Combined Operational Planning Group (AECOP) was a general nonlinear optimization model which used a totally different mathematical procedure.

Question 73. What is the Department's response to the criticism by some that the computer models used are "old and creaky?"

Answer 73. This opinion was expressed to the Management Review Team at the initiation of their review and apparently was in reference to the use of the EDIC model. This model was developed in the mid-1960s and, therefore, could be considered "old." It has been modified since then, of course. However, the economic optimization procedure remains still valid and is not a function of age. Nevertheless, we are in the process of making operational a more efficient linear program designed to evaluate a more extensive set of tradeoffs than EDIC as a replacement for EDIC. We expect this model to be fully operational and checked out by this summer.

The Uranium Enrichment Activity Simulator model was written in 1973 and has been updated several times. The current models offer several features not included in the original version. Small problem areas have been found and fixed. The model is not considered to be old or creaky.

The remainder of the models have been developed in the last 2-3 years and are certainly not "old" or "creaky."

Question 74.a. How does OUEA know that the huge complex is being managed well?

Answer 74.a. The Oak Ridge Operations Office (ORO) monitors and reviews the contractor costs and performance in all business and technical functions. Independent ORO and DOE appraisals are performed in all technical and business functions at least annually with OUEA either participating and/or reviewing each appraisal report. Cost and production goals are reviewed monthly by the OUEA operating staff and reported to the Director, OUEA. The Business/Budget Management Staff reviews and reports on budget costs and controls quarterly. OUEA reviews programs in detail at least semiannually with ORO. In the technical support area, OUEA meets frequently with contractor management and ORO to review progress and milestone accomplishments.

Capital projects are reviewed regularly with ORO and contractor management for progress and cost control. OUEA has a project control system that the contractors and ORO must follow.

Question 74.b. How does OUEA measure performance of enrichment enterprise?

Answer 74.b. OUEA measures performance of the enrichment enterprise by:

- Establishing monthly operating cost targets and analyzing variances in all major budget categories.
- Setting major controllable milestones in the Technical Support program.
- An established project control system that reports monthly progress against controlled progress milestones and costs.
- Detailed program reviews with ORO staff.

Question 74.c. How does OUEA know that the two operating contractors, Union Carbide Corporation and Goodyear Atomic Corporation, are being managed well?

Answer 74.c. The contractors are being monitored through:

- Headquarters appraisal of ORO by the OUEA, EP, NE staff
- Day to day contact with ORO staff
- Frequent visits to sites and discussions with contractor management and ORO staff
- Frequent appraisals of the contractors covering management and functional areas.

Question 75. Does OUEA have specific goals which contractors must meet?

Answer 75. OUEA sets specific goals and targets for the contractors which are used to evaluate their performance. These targets include budget controls and targets, technical support milestones, production requirements, project milestones and adherence to DOE Orders.

QUESTIONS 76 - 78

# REVOLVING FUND LEGISLATION

Question 76. Does the present budget approval process negatively impact the success of the current Uranium Enrichment Program?

Answer 76. The present budget approval process, while workable, provides firm funding levels for only one year at a time with limited flexibility to revise funding levels within the program totals. There are significant economic benefits that would accrue to the Uranium Enrichment Program if a system existed which allowed the establishment of firm multiyear funding levels.

Further, a system which allows the Program flexibility to revise funding levels of specific program components as economic opportunities and market conditions change would be desirable.

Question 77. Would a revolving fund significantly help the Office of Uranium Enrichment and Assessment carry out its objectives more expeditiously?

Answer 77. Yes, the basic advantage of the revolving fund concept is that it would allow the Office of Uranium Enrichment and Assessment to plan and execute the enrichment enterprise in a more business-like manner. A revolving fund would allow the program managers to (1) select a mix of operating and capital projects that optimizes total operations; (2) optimize project and plant scheduling between fiscal years; (3) improve cash management; (4) allocate financial resources in response to changing market conditions; and (5) increase emphasis on long-term economics.

| | |
|---|---|
| Question 78. | Would the program be as responsive to policy changes, both in the Executive branch and the legislative branch under a revolving fund? |
| Answer 78. | Yes, revolving fund legislation can contain controls requiring Executive branch and legislative branch authorizations before commitments are made for major plant expansions or other major investments. Because the enterprise would still be a wholly controlled Government entity, policy responsiveness would not be lessened as a result of revolving fund enactment. |

QUESTIONS 79 - 86

## URANIUM RESOURCES AND STATE OF THE DOMESTIC URANIUM PRODUCING INDUSTRY

| | |
|---|---|
| Question 79. | What is the current price of uranium, and how has it fluctuated over the past decade? |
| Answer 79. | The domestic price of uranium is obtained through uranium marketing and price surveys conducted by the Department. Prior to 1973, price information was not gathered by the survey. Beginning with 1973, the weighted average of natural uranium contract prices, including prices of settled market price contracts, have been: |

| Calendar Year | Price per Pound $U_3O_8$ |
|---|---|
| 1973 | $ 7.10 |
| 1974 | 7.90 |
| 1975 | 10.50 |
| 1976 | 16.10 |
| 1977 | 19.75 |
| 1978 | 21.60 |
| 1979 | 23.85 |
| 1980 | 28.15 |
| 1981 | 31.00 (Estimate) |

Question 80. What is the current total uranium (i) mining and (ii) milling capacity in the United States, and how does this figure compare with total capacity during the last 10 years?

Answer 80. It is difficult to speak independently of mining and milling capacity. Mines are designed to produce the amount of ore that a mill can process. It is better to consider mine-mill complexes as production centers. In considering the capacity of the domestic production centers, it is appropriate to determine the capacity of the mills in the United States.

The estimated total nominal capacity (in tons ore per day) of mills operable in the United States, and the percent of capacity represented by annual production levelized to 365 days per year operation, is shown below.

| Year | Tons Ore Per Day Nominal Capacity | Production as Percent of Capacity |
|---|---|---|
| 1972 | 29,500 | 50 |
| 1973 | 29,400 | 61 |
| 1974 | 28,700 | 72 |
| 1975 | 30,000 | 64 |
| 1976 | 31,210 | 76 |
| 1977 | 35,960 | 79 |
| 1978 | 43,060 | 91 |
| 1979 | 47,560 | 86 |
| 1980 | 53,050 | 86 |
| 1981 | 55,800 | 69 |

Question 81. Given the present estimate of reserves in the United States and the number of reactors in operation or under construction, what is the ability of existing reserves to supply the needs of all operating and planned power reactors in the United States during their estimate useful life, and how many additional light water reactors could be fueled and operated with such reserves?

Answer 81. Assuming a 30 year life for a power reactor, the 470,000 short tons of $U_3O_8$ reserves producible at a forward cost of $30 per pound $U_3O_8$ should be able to supply the lifetime requirements of the nearly 60 Gwe of nuclear power reactor capacity which is in operation together with those reactors under construction which are expected to begin operation by 1985. Uranium recovered at a cost of $30 per pound $U_3O_8$ would be expected to require prices averaging about $45 per pound.

The 787,000 short tons of $U_3O_8$ reserves producible at a forward cost of $50 per pound $U_3O_8$ should be able to supply the lifetime requirements of the operating power reactors plus those under construction which are expected to begin operation by 1995.

The 1,034,000 short tons of $U_3O_8$ reserves producible at a forward cost of $100 per pound $U_3O_8$ should be able to support the lifetime requirements of the operating power reactors plus an additional 120 Gwe of nuclear power capacity for a total of about 180 Gwe of nuclear power reactor capacity. Based on the latest DOE most likely forecast, this amount of nuclear power reactor capacity is not expected to be reached until the next century.

Question 82. What is the total amount of foreign uranium purchased last calendar year by domestic firms for use in the United States, and what percentage of domestic requirements is this amount?

Answer 82. Based on nearly complete data from our most recent market survey, about 3,800 short tons of $U_3O_8$ were imported by U.S. firms in calendar year 1981. However, of that total, about 1,500 tons was from settlement of previous litigation, so that foreign purchases amounted to about 2,300 tons. Between 16,000 and 17,000 tons of domestic-origin $U_3O_8$ were purchased by U.S. firms in 1981. Thus, foreign uranium purchases amounted to about 12 percent of total purchases.

Question 83. What is the total amount of domestic uranium sold to buyers for export?

Answer 83. Based on our latest published information, the sales commitments of domestic firms to foreign buyers are:

| Calendar Year | Short Tons of $U_3O_8$ |
|---|---|
| 1981 | 1,800 |
| 1982 | 1,400 |
| 1983 | 1,500 |
| 1984 | 700 |
| 1985 | 700 |
| 1986 | 600 |
| 1987 | 600 |
| 1988 | 600 |
| 1989 | 300 |
| 1990 | 300 |

Question 84. Dr. Dillon. Your testimony indicates that there are and have been restrictions on the enrichment of foreign-origin uranium for domestic end use. Are there similar restrictions on the amount of uranium that can be Imported?

Answer 84. There are no limitations on the amount of uranium which can be imported. However, a Nuclear Regulatory Commission license is required to possess the uranium.

Question 85. Is the Department considering restricting the amount of foreign-origin uranium which can be enriched in the United States pursuant to its charter in the Atomic Energy Act "to assure the maintenance of a viable domestic uranium industry..." (Sec. 161(v)?

Answer 85. There are no plans to revise the schedule for removal of the restrictions on the enrichment of foreign uranium for domestic end use. This schedule permits 60 percent of a domestic enrichment services customer's 1982 feed deliveries to be of foreign-origin. The percentage is scheduled to increase to 80 percent in 1983 and beginning in 1984 there would be no established limit on the enrichment of foreign-origin uranium for domestic end use.

Question 86. How many countries are presently supplying uranium to domestic utilities, and what is the projected stability of these sources?

Answer 86. Since 1977, when foreign-origin uranium could be enriched for domestic end use, about 40 percent of the foreign uranium came from Canada, 20 percent came from South Africa, 20 percent came from Australia, and 20 percent came from France (which includes its African suppliers Niger and Gabon). These same countries are expected to continue to supply uranium to domestic users. These sources are expected to be able to produce uranium in the future.

QUESTIONS 87 - 91

# URANIUM RESOURCES ASSESSMENT PROGRAM

Question 87. What will be the achievements of the Uranium Resource Assessment Program during Fiscal Year 1982?

Answer 87. The data remaining from the National Uranium Resource Evaluation (NURE) program, such as from the National Airborne Radiometric Surveys and the Hydrogeochemical and Stream Sediment Surveys, will be put into reports and other forms that will be useable to the public and other government agencies. An estimated 800 to 1000 formal data releases are planned for Fiscal Year 1982. A final report summarizing the objectives, strategies and accomplishments of the NURE program is planned.

The other extensive earth science data will be accurately referenced and put into a form for release to the public and to facilitate the accessibility and usefulness of the data.

The data and related reports will be available as reports, microfiche or computer tapes. The reports will be open-filed at over 15 libraries throughout the United States. All information will be available for sale from the Department of Energy.

Question 88. What specific activities are scheduled to be performed under this program during Fiscal Year 1983?

Answer 88. Any NURE reports that have not been issued will be released to the public and open-filed.

Government and contractor personnel will be terminated, equipment will be transferred to other government agencies or disposed of, and physical facilities will be transferred to other government agencies or will be closed down. Any necessary decontamination of equipment and facilities will be scheduled.

Question 89. What have been the accomplishments of the Uranium Resource Assessment Program since its foundation?

Answer 89. The Uranium Resource Assessment Program began in FY 1971. Prior to that year, the main functions of the Government's natural uranium program were to purchase uranium ore and concentrate and to search for uranium in the United States.

The Uranium Resource Assessment Program has had a continuing core subprogram. This core subprogram has estimated uranium reserves based on proprietary industry data, analyzed uranium supply, assessed potential uranium resources, developed improved methodology and technology for resource identification, and assessed and supported international activities to estimate the world uranium resource base.

In FY 1974, the National Uranium Resource Evaluation (NURE) program was started. NURE, which was a part of the Uranium Resource Assessment program, was a massive data gathering program to help assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurence of uranium in the U.S. The NURE program was terminated on September 30, 1980. In October 1980, a publication was issued entitled "An Assessment Report on Uranium in the United States of America," which was based on data provided by the NURE program and by industry sources.

Some one million flight line miles were flown under the NURE National Airborne Radiometric Survey program, covering all 468 of the 468 National Topographic Map Series (NTMS) quadrangles in the conterminous U.S. and 98 of the 153 quadrangles in Alaska. These data are being used to construct a total radiation exposure-rate map of the U.S.

The NURE Hydrogeochemical and Stream Sediment Surveys covered more than 75 percent of the Nation at a sampling density of one sample per 5 to 10 square miles, for a total of about 750,000 samples. The samples were analyzed for uranium and up to 42 other elements using delayed neutron activation, plasma-source and arc-source emission spectrography, fluorometry, atomic-absorption spectrophotometry, X-ray fluorescence, and isotope-dilution mass spectrometry.

Some 435,000 feet of drilling and coring was accomplished for NURE in rocks ranging from crystalline rocks of Precambrian age to evaporites of Quaternary age. Research into advanced methods for geophysical logging concentrated on field demonstration of the Prompt Fission Neutron system, and other efforts in geophysical logging improved data reduction and analysis methods for spectral logs and for gross gamma-ray logs, resulting in more quantitative field logs with higher accuracy. The objective of the NURE National Logging Program was the acquisition of quantitative radiometric log data from holes drilled for purposes other than uranium exploration; almost 3 million feet have been logged.

Technology integration projects had three objectives: to detect halo effects surrounding uranium deposits in different geologic environments, to develop genetic models, and to develop cost-effective methods for uranium exploration and resource assessment.

Since 1976, some 2,000 individual reports have been issued. Almost 85,000 copies of these reports have been distributed through the Department's Grand Junction, Colorado, Technical Library.

Question 90. What has been the increase in the estimated uranium reserves in this country over the last 10 years and to what extent has any such increase been due to the efforts of the Uranium Resource Assessment Program?

Answer 90. The historical and current estimates of uranium reserves are listed below by forward-cost category. The reserves in each cost category include all reserves in the lower cost categories.

Historical and Current Estimates of Uranium Reserves

| | Thousand Tons $U_3O_8$ | | | | |
|---|---|---|---|---|---|
| Year | $8/lb$U_3O_8$ | $15/lb$U_3O_8$ | $30/lb$U_3O_8$ | $50/lb$U_3O_8$ | $100/lb$U_3O_8$ |
| 1/1/72 | 273 | 520 | - | - | - |
| 1/1/73 | 272 | 520 | - | - | - |
| 1/1/74 | 277 | 520 | 634 | - | - |
| 1/1/75 | 200 | 420 | 600 | - | - |
| 1/1/76 | - | 430 | 640 | - | - |
| 1/1/77 | - | 410 | 680 | 840 | - |
| 1/1/78 | - | 370 | 690 | 890 | - |
| 1/1/79 | - | 290 | 690 | 920 | - |
| 1/1/80 | - | 225 | 645 | 936 | 1,122 |
| 1/1/81 | - | 112 | 470 | 787 | 1,034 |

Except for depletion of reserves by mining, these reductions are due to rising production costs and do not indicate a decrease in the amount of uranium present in the ground. Depletion consists of two reductions to reserves: (1) a prorated quantity of actual mine production, based on production grade compared to the reserve grades at various cost categories, and (2) the amount of uranium-bearing material not recoverable in the future at the given cost level as a result of the mining of lower cost reserves.

The Uranium Resource Assessment Program has comprehensively assessed the Nation's uranium resources and, in so doing, has identified those geographic and geologic environments in which potential resources may occur. In addition, concentrated efforts were made to improve and develop equipment, techniques, and procedures to aid in uranium exploration and evaluation.

However, the Uranium Resource Assessment Program was not a uranium exploration program. The actual search for minable deposits in the U.S. remains the responsibility of uranium exploration companies. Although many of the Uranium Resource Assessment Program studies and investigations have assisted uranium companies in their exploration activities, we cannot isolate the extent to which resource estimates increased due to the Program.

Question 91. What is the total amount of federal funds expended on the Uranium Resource Assessment Program from its inception through Fiscal Year 1982?

Answer 91. The Uranium Resource Assessment Program began in FY 1971. The National Uranium Resource Evaluation (NURE) program began in FY 1974. Through FY 1982, $310 million will have been spent by the Government on these efforts.

QUESTIONS 1 - 19

# QUESTIONS FROM MINORITY MEMBERS

QUESTIONS 1 - 9

Question 1. On March 8, at the FY '83 appropriations hearings, Shelby Brewer testified that a viable uranium production industry is comprised of the companies that remain after market adjustments have been made. Is it DOE's position that a few companies' survival, with heavy reliance on foreign suppliers, equates with a viable industry?

Answer 1. Based on past experience, we see no evidence of a heavy reliance on foreign uranium suppliers by domestic utilities. In the 5 years that foreign origin uranium could be used in U.S. nuclear power reactors, only 8 percent was of foreign origin, compared with an allowable weighted average of 22 percent.

We project that uranium requirements in the mid-1980's of about 15,500 short tons of $U_3O_8$ per year will be needed to fuel domestic power reactors. These requirements are projected to grow to about 20,000 tons by 1990. A considerable number of uranium producing companies are expected to be operating to meet these requirements.

Question 2. The Atomic Energy Act requires the DOE to maintain a viable uranium industry. What basis in the Act do you have for this new definition of a viable uranium industry?

Answer 2. The Atomic Energy Act of 1954, as amended, does not "require" the DOE to maintain a viable uranium industry. Section 161v provides that DOE "to the extent necessary to assure the maintenance of a viable domestic uranium industry" shall not offer its enrichment services to enrich foreign-origin uranium for domestic end use. However, the Act provides no definition of viability or other guidelines to determine the appropriate specific conditions for relaxation or removal of restrictions on the use of foreign-origin uranium for domestic end use. Dr. Brewer's testimony did not provide a new definition of viability. Rather. it was an observation that the companies that remain in the uranium industry, after adjustments are completed over the next few years, should constitute a viable industry.

Question 3. What then, specifically, constitutes a viable uranium industry? What should the industry be capable of doing in terms of exploration and producing capability?

Answer 3. There is no definition of what constitutes a viable uranium industry. Factors which should be used to assess the viability of the industry include:

- Size of the market and the rate of growth of future uranium requirements.
- Price of uranium and the adequacy of prices to assure a healthy industry.
- Size of domestic ore reserves and potential resources.
- Rate of development of new reserves.
- Adequacy of funds for exploration and construction of new mines and mills.
- Probable penetration of the domestic market by foreign imports.
- Size of the export market.
- Capability for domestic self-sufficiency.

The industry must be capable of having adequate funds to explore for uranium and to provide production capability.

Question 4. What do you believe it would take to reverse the decline of the domestic uranium industry?

Answer 4. A revitalization of the nuclear power industry is required to improve the health of the domestic uranium industry. Like many portions of nuclear fuel cycle, the uranium producing industry has excess capacity because the nuclear power growth and fuel demand that was projected a few years ago has not materialized. However, we believe the nuclear industry will begin to rebound as more nuclear power reactors are licensed for operation. The Administration is taking steps to stimulate the nuclear power industry.

Question 5. Are you aware that nearly all recent uranium sales to U.S. utilities have been made by foreign producers?

Answer 5. Based on nearly complete data received on the most recent survey of the uranium market, in 1981 uranium sales of domestic uranium producers to U.S. uranium users (which include utilities and reactor manufacturers) amounted to between 16,000 and 17,000 short tons $U_3O_8$. In the same year, about 3,800 tons was imported into the United States by domestic companies. However, of that amount, 1,500 tons was from settlement of previous litigation. Thus, we would not conclude that nearly all recent sales to U.S. utilities have been made by foreign producers.

| | |
|---|---|
| Question 6. | Suppose that all of the new requirements for uranium were filled by imports. What action would you recommend be taken and when would you recommend that action be taken? |
| Answer 6. | It would depend on what portion of the total domestic requirements the imports represented. Most of the domestic requirements are being met by existing contracts with domestic producers. There is a small unfilled demand not yet under contract. If these small demands were filled by imports, they would only amount to a modest portion of total sales and no action should be taken to change the schedule for permitting the use of foreign uranium in domestic nuclear power reactors. |

Question 7. What impact do these recent foreign sales have on the U.S. producer?

Answer 7. Since foreign sales only represent a small portion of total domestic uranium usage, the sales have a modest impact on the U.S. producer.

Question 8. Are you aware that a major U.S. producer has elected to purchase foreign uranium to meet his contractual commitments rather than produce? Are you aware that foreign governments have approached other major producers offering to sell substantial quantities of foreign uranium at prices below U.S. production costs?

Answer 8. We are aware that a U.S. producer has purchased foreign uranium rather produce the uranium in his facilities. We are aware that other producers have been contacted, but we are not aware that substantial amounts are being offered at prices below U.S. production costs.

Question 9. What does this development (In Question 8) indicate about the current status of the U.S. producer?

Answer 9. This development indicates that a certain amount of U.S. production capacity cannot produce uranium at a cost lower than the price of foreign uranium. The cost of production from these increments of capacity is higher because, among other reasons, the ore grade is lower than in foreign countries and the ore occurs at greater depths in the United States.

QUESTIONS 10 - 17

# ENRICHMENT PRICING

| | |
|---|---|
| Question 10. | Has DOE lost enrichment business to foreign competition as a result of lower prices or as a result of anticipated price increases by DOE? |
| Answer 10. | Because of increases in DOE enrichment prices over the last few years and the strengthening of the U.S. dollar compared to foreign currencies, DOE has lost its previous pricing advantage in the near-term enrichment market. Some sales have been lost as a result, although it is difficult to pinpoint them exactly because other reasons were also operative in customer decisions to select another supplier. Because of the current surplus of enrichment services in the marketplace, price is a major factor in customer buying decisions. |

There is the perception among DOE customers that since DOE enrichment services are government controlled, the government can unilaterally--and arbitrarily--increase enrichment prices at will, leaving foreign utilities with the impression of having no future price security. Although DOE is pursuing several efforts to counter this notion (pricing brochures, newsletters, marketing visits), it has contributed to the loss of sales in the foreign market. This notion, coupled with the perceived uncertainty of 4-year Presidential terms, (demonstrated by the substantial shifts in policy between the Carter and Reagan Administrations) has left potential foreign customers with a lack of confidence in the stability and continuity of enrichment policies, especially with regard to pricing. Although the promise of low future prices from DOE's advanced enrichment technologies is alluring, the stigma of political unpredictability remains.

Aside from the pricing issue, there are two major motivations for customers to contract with suppliers other than DOE: (1) the desire (and in some cases the pressure) to support national or partnership enrichment production (e.g., FRG and the Netherlands for Urenco; France, Belgium, Italy and Spain for Eurodif); and (2) the inclination toward diversification of supply sources to reduce assurance of supply risks.

Question 11. Is DOE aware of additional enrichment work which will be lost to foreign sources of supply or which is in jeopardy as a result of current or anticipated price policy?

Answer 11. It is impossible to single out pricing policy as the sole factor contributing to the loss of a foreign sale. The answer to Question 10 identifies two other factors (nationalism and diversification), in addition to which the following factors also influence a buyer's choice of enrichment supplier: national goals and politics, supply assurance, contractual flexibility, customer services, financing and package deals.

However, as the economic situation worsens in most nuclear energy producing countries, power utilities are forced to consider the price factor with increasing priority. Although maintaining the lowest SWU price will not guarantee additional sales, low price and price predictability will be increasingly key factors for most enrichment-purchasing utilities.

The near-term pending enrichment sales for which DOE must compete against the other suppliers are Mexico and Taiwan. Competition for possible follow-on contracts also exists for the Federal Republic of Germany and the Netherlands.

Question 12. Under the Atomic Energy Act of 1954, the price of U.S. enriching services has been and continues to be based upon the policy of "recovery of the government's cost over a reasonable period of time." In application, the calculation of the price of a unit of enrichment (Separative Work Unit or "SWU") is directly dependent upon the projected costs versus the anticipated sales backlog over a rolling 10-year advance period. Any error in forecasting or loss of anticipated sales to more competitive pricing automatically requires higher, less competitive prices for enrichment.

Does DOE view this policy as constraining its ability to market its services? How would you modify this statutory requirement? How would such a modification effect domestic electricity consumers who pay for nuclear-generated power?

Answer 12. DOE does not consider cost recovery pricing as constraining its ability to market enrichment services, and recommends against any major change in the existing pricing policy. DOE and the majority of its customers view the current cost recovery policy as a reasonable pricing method. Whereas the loss of anticipated future sales can have the effect of increasing the DOE price, the impact of these losses can be offset through corresponding reductions in production costs. DOE updates its forecast and operating plan annually, selecting the most feasible economic plan, and utilizes this base in establishing its enrichment charges. A primary objective in establishing these plans is minimization of separative work costs. By optimizing its production strategy and production costs, DOE can maintain competitive prices at various demand levels.

It is important to note that the major driver behind the current DOE enrichment price is the cost of power to the diffusion plants. The key to maintenance of competitive DOE prices is early introduction of less costly gas centrifuge production capability rather than modification of the cost-recovery pricing method.

Question 13. The current DOE forecast of future enrichment services required is questioned by most independent authorities on nuclear power and they claim that your projections contain enrichment work for reactors which have, by public announcement, been cancelled or indefinitely deferred. Would you comment on this charge? What limits of error are placed on your forecasts, and to what extent does this variance increase the price in order to achieve the "full cost recovery" goal?

Answer 13. At the time that our forecasts were prepared, there were, to our knowledge, no reactors included that had, by public announcement, been cancelled. There were a few instances of projects on hold status where it was assumed that the projects would be restarted and available primarily in the very late 1990s on the bais of economics and load growth projections. There have, of course, been recent cancellations of projects, many of which were well underway, that we did not anticipate would be cancelled in last year's forecast. These cancellations will be reflected in our next forecast.

We currently do an assessment of a reasonable low-high variance around the "mid" forecast on a reactor by reactor basis for sensitivity analysis. The pricing update is done assuming the "mid" case requirements over the ten year pricing period. To the extent that additional cancellations or delays occur, they are reflected in the pricing update made the following year. Forecasts which err on the high side would have the effect of lowering the price; those that err on the low side would increase the price. By updating the forecast and the price annually, DOE attempts to minimize the perturbations in the price due to changes in demand.

Question 14. The only new foreign contract for enrichment services for a foreign reactor has come from Egypt. Does DOE have plans to assert a more aggressive marketing position, realizing the real world of overcapacity and competitive pricing?

Answer 14. DOE is pursuing an aggressive marketing approach with increased customer contacts and visits (to elicit follow-on commitments for expiring contracts); identification and exploration of potential new enrichment sales, i.e., Mexico, Yugoslavia, Taiwan, South Korea, Japan; and on-going internal review efforts to effect improvements in DOE's market competitiveness, especially in contractual terms and conditions. DOE's major selling points remain its technical reliability and its price. Despite currency fluctuations which are presently rendering DOE's price slightly higher than our competitors', DOE is in a strong position for stable and competitive future prices due to the development and scheduled deployment of advanced enrichment processes.

Question 15. In 1981, DOE recorded $38.1 million of net revenue resulting from the sale of enriched inventory, previously produced under the "split tails" option, equivalent to 1.25 million pounds $U_3O_8$. This transaction is in direct competition with U.S. uranium producers. In their current projections of enrichment prices, to what extent does DOE depend upon the revenues from such future sales of government-owned inventory?

Answer 15. Let us first consider some background information. In 1972 the U.S. Government declared that a portion of its uranium inventory, then estimated at around 50,000 short tons $U_3O_8$, was surplus to projected Government requirements. Various alternatives were considered to dispose of the surplus inventory. The Government rejected the option of explicit sales because of the adverse impact such sales would have on the domestic mining industry.

An alternative use of the surplus uranium was developed to avoid competition with domestic producers and the associated impact on the market price structure. This is possible because natural uranium can, to some extent, be used as a substitute for uranium enrichment services. From July 1972 to October 1978, the operating tails assay of the enrichment plants was increased while leaving the transaction tails assay unchanged. When the operating tails assay is greater than the transaction tails assay, the situation is called "split tails" operation. The transaction tails assay determines the amount of enrichment services an enrichment services customer must purchase from the Government, and the amount of natural uranium the customer must purchase from the mining industry and deliver to the Government's enrichment facilities. By leaving the transaction tails unchanged, the Government did not change the need for uranium at the enrichment plants. Indeed, the transaction tails assay has remained at 0.20 percent U-235 since the Government began offering enrichment services in 1969.

At the higher operating tails assay, the customer-provided uranium was insufficient to produce the enriched uranium required by the customer. The Government provided the additional uranium from its surplus stocks and the enrichment customer was charged for this uranium through the payments for enrichment services. The Government, in effect, substituted some uranium for separative work. This method of operation was discussed during Congressional hearings in March 1972. Congress had no objection to the split tails operation.

Since the mid-1960's, the Government has preproduced enriched uranium by using available excess separative work capacity and using its own stockpile of natural uranium. Preproduction occurred during years when the tails assays were the same (often called "unified tails" operation), as well as during the years of split tails operation. The preproduction of enriched uranium was undertaken because long-range economic studies indicated it was less expensive to produce the separative work in the near-term from the existing plants than to produce it in the long-term from new plants.

The Government's stockpile of enriched uranium is contained in cylinders in the form of $UF_6$. Currently, some cylinders contain enriched uranium that was produced during unified tails operations, while others contain enriched uranium produced during split tails operations. The Department's nuclear materials management system maintains records for each cylinder to reflect whether the enriched uranium was produced during unified tails or split tails operations.

In order to save budget costs, electric power purchases to operate the gaseous diffusion plants have been reduced, thus reducing the separative work output of the plants. In order to provide the enriched uranium required by enrichment services customers, some of the enriched uranium from the Government's stockpile must be used, and will be taken from cylinders produced during unified tails, as well as split tails operations. The Department's accounting system records a transaction for natural uranium usage only when a cylinder is used that contains enriched uranium produced during split tails operations. As noted earlier, some of the Government's natural uranium is still in the stockpile of enriched uranium produced during split tails operations. Therefore, some of the natural uranium consumed during split tails operations has not yet been recorded as a transaction. At the current rate of enriched uranium usage, we expect some of the Government's uranium from split tails operation to be recorded as a transaction over the next 5 to 10 years. However, the accounting treatment does not in any way affect the quantity of Government owned uranium now being fed to the enrichment plants to meet Government requirements nor the amount of natural uranium that enrichment services customers currently bring to the enrichment plants. DOE is not "selling" uranium but is only accounting for material used during past production of an enriched uranium inventory in the July 1972 to October 1978 period.

Question 16. Recognizing the considerably greater cost efficiency of the gas centrifuge process over the gaseous diffusion process, should not the research and development costs of this project be accumulated and subsequently written off in conjunction with the capital costs when this project assumes production status as a means of "holding the line" on current enrichment prices?

Answer 16. All research and development costs in uranium enrichment, including gas centrifuge, are expensed and recovered in the SWU charge as incurred. This treatment is consistent with current cost accounting standards (Reference: Cost Accounting Standards Board Statement No. 2 and Cost Accounting Standards Board Regulation No. 420). We certainly agree that the gas centrifuge process is cost efficient and is a key element in "holding the line" on SWU prices. However, capitalizing research and development costs will not necessarily reduce prices because interest costs must be imputed on all capitalized costs and for uranium enrichment accounting all interest costs are expensed as incurred.

Question 17. In the event that continued erosion of the DOE enrichment backlog does not support the need to maintain the current diffusion capacity until the centrifuge project reaches production capacities (if indeed this is not already the situation), has DOE projected the impact on enrichment prices that an early phasing out of diffusion capacity would entail? Would not the cost ramifications of such rescheduling make the continuance of a competitive enrichment price the preferable course?

Answer 17. We have not really evaluated the impact on the price of enrichment services of shutting down diffusion plants prior to the Gas Centrifuge Enrichment Plant (GCEP) achieving production status. Any such plan would, in our view, be premature and entail high risk unless future demand is assured to be significantly lower than currently expected. At a minimum, we would need some GCEP operational experience and clarification of political, technical, and budget uncertainties which could affect the availability of future gas centrifuge capacity before committing to shutdown of any gaseous diffusion plants.

QUESTION 18

# ADVANCED ISOTOPE SEPARATION

Question 18. As you know, DOE has under consideration three AIS technologies and is expected to choose one for engineering development in April. Has DOE considered designating a backup process in case the primary process is not successfully developed? What would be the criteria for a backup process?

Answer 18. The Department has selected the AVLIS process to proceed into the next phase of the RD&D program. However, no request for DM funding is anticipated until the thermal control issue associated with operation of the uranium collector has been resolved. In addition, the Plasma Separation Process (PSP) research effort would be continued, subject to the availability of funds, for the next two years. The rationale for this action is that the exploration of process improvements of a PSP process could also offer potential application when considering the broad interests of the Department and specifically the Special Isotope Separation (SIS) Program.

QUESTION 19

# QUESTIONS FOR MR. VOIGT

Question 19. Section 161(v) of the Atomic Energy Act, which provides your authority to operate the DOE uranium enrichment program, says the following:

> And provided further, that the Commission, to the extent necessary to assure the maintenance of a viable domestic uranium industry, shall not offer such services for source or special nuclear materials of foreign-origin intended for use in a utilization facility, within or under the jurisdiction of the United States.

The latest EIA report to the Congress contained some very disturbing conclusions about the health of the U.S. uranium mining and milling industry:

> Under the current Federal policy, which will allow unrestricted imports of foreign uranium beginning in 1984, foreign suppliers could capture about half of the U.S. market by the 1990's, implying a domestic uranium industry reduced to about half its current size.

If half of the domestic utilities will be utilizing foreign uranium, which you are prohibited from enriching, what do you estimate will be the amount of capacity that you can enrich?

Answer 19. The section-by-section analysis of the bill leading up to Section 161v of the Atomic Energy Act of 1954, as amended, indicates that the statutory direction to the then Atomic Energy Commission regarding the availability of enrichment services for foreign-origin uranium is "flexible both as to the duration and degree of the restriction" and it contains the following statement of purpose:

> Accordingly, the language of the bill will permit the Commission to survey periodically the condition of the domestic and world uranium markets and to offer or refuse to offer its enrichment services on a basis which will assure, in its opinion, the maintenance of a viable domestic uranium industry".
> 2 US Code and Administrative News, p. 3135, 1964, 88th Cong (2d).

When it appeared that restrictions on foreign uranium could be eased without affecting the viability of the uranium industry, the Atomic Energy Commission, after careful study and Congressional review, put into effect a plan for gradual removal of restrictions on enrichment of imported uranium for domestic end use. The plan, which was announced in 1974, provided that in 1977 up to 10 percent of uranium furnished by an enrichment services customer for domestic end use could be of foreign origin. The amount would be increased to 15 percent in 1978, 20 percent in 1979, 30 percent in 1980, 40 percent in 1981, 60 percent in 1982, and 80 percent in 1983. Starting in 1984 there would be no restrictions.

Thus, the Government is not prohibited from enriching uranium from domestic enrichment services even if half of the uranium were from foreign sources. Indeed, this year up to 60 percent of the uranium furnished by a domestic enrichment services customer could be of foreign-origin. However, over the 5 years that foreign-origin uranium could be used in domestic nuclear power reactors, only 8 percent of the uranium was of foreign origin, compared with an allowable weighted average of 22 percent.

# FISCAL YEAR 1983 DEPARTMENT OF ENERGY BUDGET REVIEW

---

## WEDNESDAY, MARCH 31, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
*Washington, D.C.*

The subcommittee met, pursuant to notice, at 9 a.m., in room 2325, Rayburn House Office Building, Hon. Marilyn Lloyd Bouquard (chairman of the subcommittee) presiding.

Present: Representatives Bouquard, Volkmer, and Lowery.

Staff present: Dr. Harlan Watson and Joyce Gross Freiwald.

Mr. **Volkmer** [acting chairman]. Good morning.

We will proceed and if the witnesses will please come to the table, Congresswoman Bouquard will join us in a little bit. She has been delayed but I would like her statement to be made a part of the record.

[The prepared statement of Congresswoman Bouquard follows:]

### Prepared Statement of Hon. Marilyn L. Bouquard, a Representative From the State of Tennessee

Good morning, ladies and gentlemen. Today the Subcommittee will continue its review of the Department of Energy's Fiscal Year 1983 budget request for the Uranium Enrichment Program. We will be receiving testimony from industry representatives this morning, and I am pleased to say, from two of my constituents from Oak Ridge, Tennessee: Mr. Dick Grant, President of Boeing Engineering & Construction, S.E., Inc., and Dr. Bob Merriman, Director of Enrichment & Technology at Union Carbide. Dick, and Bob, welcome here today. We are looking forward to hearing your testimony, as well as that of our distinguished witnesses from Goodyear Aerospace Corporation, represented by its President, Mr. Bob Clark; and from the Garrett Corporation, represented by Mr. William H. Sutton, Manager of the Commercial Gas Centrifuge Project, accompanied by Mr. W. E. Sullivan, Manager of the Washington, D.C. office.

We are very interested in hearing these outside assessments of the Department's Uranium Enrichment Program, as well as receiving their advice concerning possible improvements to the current program's content. I would like to, at this time, turn over the proceedings to Congressman Harold Volkmer of Missouri, who has been a strong supporter of the Subcommittee program and a constructive critic of the Administration's energy R&D budget. Harold, it's a continuing pleasure to serve with you on the Subcommittee. And before I give you the gavel, I want to warn the witnesses that Mr. Volkmer's style is to get to "the heart of the matter." Be prepared for some tough questions.

Harold, it's all yours.

Mr. **Volkmer**. I am Congressman Harold Volkmer of Missouri and I will be chairing the remainder of today's hearing in the absence of the chairman for most of the morning.

Today the subcommittee will be receiving testimony from industry representatives on the Department of Energy's uranium enrichment program.

We will be hearing representatives from Boeing, Goodyear Aerospace, and Garrett Corp. discuss their firms' participation in the DOE's gaseous centrifuge program, as well as their views and concerns about DOE's program for the construction of the gaseous centrifuge enrichment plant [GCEP] at Portsmouth, Ohio. We are also expecting to receive some comments on current legislative initiatives to establish a revolving fund for the uranium enrichment enterprise.

We will also be receiving testimony from Union Carbide representatives who have been deeply involved in the research and development of advanced enrichment technologies, including gas centrifuge and advanced isotope separation technology.

Our first witnesses will be appearing today in a panel. The panel participants include Mr. Richard L. Grant, president of Boeing Engineering & Construction, SE., Inc.; Mr. Robert W. Clark, president of Goodyear Aerospace Corp.; and Mr. William H. Sutton, manager, commercial gas centrifuge project, Garrett Corp. Mr. Sutton will be accompanied by Mr. W. E. Sullivan, manager of the Garrett Corp. Washington, D.C., office.

Gentlemen, I would like to welcome you here today. I would ask that each of you give your testimony in turn, and then we will ask you questions after you have all finished.

Before we proceed I would also like to say that I understand that you all have prepared testimony. That will be made a part of the record. If you wish to read the testimony that is quite all right, however, if you wish to summarize that will also be all right—either way you wish to do it.

Mr. Grant, would you proceed?

## STATEMENT OF RICHARD L. GRANT, PRESIDENT, BOEING ENGINEERING & CONSTRUCTION, SOUTHEAST, INC.

Mr. **Grant**. Thank you, Mr. Chairman.

It is a great pleasure to be here this morning and I am certainly grateful for the opportunity to present my views on the subjects that you have mentioned at the outset.

I should say that we consider this opportunity about once a year as a turning point and something that we greatly treasure. We are delighted that you have turned to industry for their views and we think we have, perhaps, some unique ones. We hope that our perspectives add something to your considerations.

First of all, addressing Boeing's participation in the gas centrifuge program, it currently includes the manufacture of the current version of the centrifuge machine. It includes value engineering tasks and tests accompanying them for improved components and subsystems for the existing machine design. It also includes research and development activities for the advanced gas centrifuges, in the vernacular known as set IV and, perhaps, V and VI machines.

Nuclear power program involvement began for both Boeing and for myself personally, in 1972 with the Rasmussen reactor safety study program. It has spanned the back end of the fuel cycle, powerplant construction, and enrichment on the front end of the fuel cycle beginning in 1974.

With President Carter's announcement of the intent to proceed with the GCEP project in 1977, we began the activities to qualify ourselves for centrifuge manufacture. Facilities and equipment were committed and about $10 million was spent to equip and develop the manufacturing capability in Seattle.

Nationwide site surveys were initiated for a new factory site specifically for the manufacture of centrifuge machines. These began in late 1978.

Two and one-half weeks after we were awarded the contract for the first phase of the GCEP machine production—in September 1979—we broke ground on a 210-acre site in Oak Ridge, Tenn., for this manufacturing facility.

The factory was designed, constructed, and equipped at a cost to Boeing of about $60 million. That factory is now in existence and in production. The first hardware fabrication and assembly began in June 1981. That followed, of course, the early fabrication effort in Seattle.

The factory is now producing centrifuge machines, as some of the subcommittee staff, including Dr. Watson, have witnessed.

The RFP that we originally responded to for this machine manufacture program required us, as a condition of qualification for the job, to commit to provide equipment, facilities, and personnel for this phase I part of the proposal. In addition, it required that we go to our board of directors and obtain a commitment to proceed on into phase II—that is a commitment again for facilities, equipment, and personnel—if we are selected.

Boeing has made that commitment. We have gone to the board and complied with those requirements in every respect. Our money is on the line today and we are proud of our facility.

My views of the program, if I may proceed with that, are best described by a set of facts which I will reference as follows:

The first fact is that the existing PIC model of the centrifuge works as planned. Its output is equal to or better than projections. Its reliability in operation will be acceptable and that reliability will be improved even more as those of us who are manufacturing the machines put them in service and make improvements.

Second, the factor of 20 or more energy efficiency improvement over the gaseous diffusion process is not speculative. One hundred metric tons of enriched uranium has been produced with the centrifuge. That is a fair sample for measuring how well we are going to do. You might want to ask some of the advocates of the advanced systems how much they have produced.

The third item is that after nearly $1 billion—and, in fact, I think we are crossing right over the $1 billion mark right now—in expenditures on GCEP, the costs have proven to be within 1 percent of the planned costs and have been so on a month-by-month basis since the inception. The program is currently $1 million under the target. I wonder how many large programs we can point to with this same pride.

Fourth is that value engineering programs will improve the life cycle costs of the centrifuge process by tens, and perhaps, hundreds of millions of dollars. Life cycle costs are those experienced over the entire depreciable life of the process.

Solid engineering tasks are in place to increase individual machine and total plant output. My confidence in their success and performance is high, and the costs will be modest. The set IV, as we call it, is very analogous to what we have done at the Boeing Co., in progressing from a 727-100 to a 727-200, 727-300, -400, and so forth--no major technological breakthroughs, improvements, changes in the fundamental technology.

Finally, 625 suppliers in 30 States are supporting us—that is just our part of the program—and some of these people have made capital investments to provide the parts and materials that we are buying from them.

In summary, as my views are concerned, the same factors that attracted the Boeing Co., to this program in the first place, namely good technology and good economics, continue to be attractive. The technology and the cost effectiveness look better than they did in the mid-1970's, as cost targets are met, as electricity costs continue to escalate, and as proven production capacity is in place and working. This gives us confidence. We feel very comfortable that the program is in good shape.

I have some concerns for the program. My concerns are that, as with any capital project, when you start to slide schedules and you start to expect more over a longer time period for the same amount of money, it will not happen that way. As you start to slide these things, the ability to manage to the total estimated cost at completion will simply evaporate.

Further, we have lost opportunities to save money and, more importantly perhaps in some areas of the country, to save energy. These lost opportunities are not being properly considered in most quarters.

I am concerned that the basis for making decisions on this project, both in terms of its size and its pace, are being obscured by the kinds of analyses that are being conducted by looking at the total enterprise. Those huge costs tend to submerge the kinds of cost benefits that are available from the centrifuge.

Finally, in that regard, tying the centrifuge project to demand is a mistake; it need not be done, and it clouds an issue that need not be clouded.

I want to address the demand question first. The only thing that we need to consider seriously in this case is whether or not there will, at any point in time in the future, be a demand for 8.8 million SWU's of capacity. It is unimportant whether we project for purposes of this analysis that there will be 26 million SWU's capacity required in the year 2000. The question is, Will there be a requirement for 8.8 million SWU's? Of course there will. Will there be a requirement for 13.2 million SWU's in the case of set IV—because that is the capacity that you get by retrofitting set IV into the program?

Every year that those minimal quantities—8.8 or 13.2 million SWU's of separative work—are produced by gaseous diffusion, between 18.9 and 28.3 billion more kilowatt hours of electricity are paid for and consumed than need be. That is enough electricity for something over 1 million American households.

Therefore, assuming that these modest demands will continue to exist, the rationale for GCEP can be decoupled from enrichment demand. Then GCEP can be treated as it should be on its own merits and we may compare it with the diffusion process that is currently being employed. If you accept these conditions, then we can make our decisions on the basis of economics and conservation and they will be simpler. The impact of any decisions made regarding them in the form of time-schedule relationships or in the form of the size of the project will be made clear.

Let us look at some historically factual information. This is not information that I have invented. This was taken from the DOE uranium enrichment report.

Electricity for uranium enrichment has escalated since 1973 at 20 percent per year on the average, or on the average, 10 percent per year over inflation. This aberration—if you can call it that—of 9 years' duration may be moderated in the future but, I confess, I see very little at work in our economy today to suggest that significant and long-sustained moderation of inflation and escalation factors will occur.

DOE is currently using, in some of its estimates, a range of between 1½ and 3 percent escalation for electricity over and above the general inflation rate. My own assessment of that, in the Tennessee Valley area in particular—and I am less certain of this in the case of OVEC and EEI which are the other two electricity suppliers—is that it is virtually a certainty with the cost of money and with the situation they have with capacity, that that number will be at least 4 percent over a very long time period in the future.

It is clear, in any case though, that inflation will remain with us and that escalation of the cost of energy, and electricity in particular, will remain with us.

If we may ignore demand then, and proceed on to make our comparisons in a more rational way, we can determine the cost benefit of the centrifuge by simply determining how much it will cost over the lifetime of the project to produce the number of SWU's of capacity that it has the capability for and then compare those costs with the costs for producing that same capacity using the gaseous diffusion process—same number of SWU's, same period of time.

If the cost difference that you determine by this means is large enough to encompass all of the uncertainties that you may choose to assign to the various parameters involved, then it will have a net positive cost benefit. Uncertainties, of course, include things like various ways people like to treat the time value of money and there are as many different ideas as to how you treat that as there are people to think about it—or perhaps I should say economists to think about it.

There are uncertainties in terms of how you might assume the escalation of electricity. I have mentioned that and we will address that a little bit more. There are some uncertainties perhaps in how accurately you are able to predict things like the operating costs of the centrifuge over the long haul or, for that matter, what is likely to happen as gaseous diffusion gets older to cause its operating costs to escalate.

I have some figures attached to my formal testimony and I would like to refer to them now.

Figure 1 in the testimony performs the analysis that I have suggested using the 8.8 million SWU case—which is the yellow band line that you see there—and assuming that electricity, as I have said, will escalate 4 percent per annum higher than the general inflation rate. Over a 25-year lifetime of producing 8.8 million SWU's of capacity, as indicated here and I have chosen this particular 25-year period, something like $220 billion in additional costs will be expended if GCEP is not on line. We have agreed you will have to have 8.8 million SWU capacity. If you have to provide it without centrifuge, you will spend an additional $220 billion over that time.

On the other hand, if you were to constrain the GCEP to 2.2 million SWU's of annual capacity, the lower of those two lines shown on that chart—the $56 billion—would be the cost avoided over that same time period under the same conditions I have just mentioned.

We talked a little bit about the set IV machine and its maturity and my confidence in it is high as I have said.

Figure 2 shows you what the same conditions will produce if we go ahead and introduce set IV as planned in 1989 into buildings 3 through 8 and then retrofit back into the first two process buildings as appropriate.

The savings, in total, is $320-plus billion—the numbers are so large they are hard to think about. The important feature of these numbers is that what we are looking at here is the expenditure of money for the set IV program of something like half a billion dollars, including the equipment differential costs, that will produce in excess of $100 billion additional cost avoidance over that same 25-year period.

Set V and set VI machines are on the drawing board at various stages at the present time and will produce even further savings. What happens—to draw you a scenario—is that the cost of electricity to produce SWU varies almost directly with the number of SWU's. However the operating costs do not vary. The size of the plant remains fixed. The plant does not have to get any bigger to produce these additional SWU's, so, that operation costs remain fixed over that time period and the capacity of the building goes up and you get incredible cost savings. As I say, the numbers are almost too big to cope with. To help you understand the size of these numbers on the sides of these charts, I have plotted the same numbers in multiples of the fiscal year 1983 total energy program budget of some $11.6 million. It is a little easier to think, perhaps, in terms of 25 times the 1983 budget than it is to think of it in terms of $300 billion.

The schedules and the actual costs for the set V and VI machines, of course, are—as with all technology in the earlier stages of development—somewhat uncertain. However, we have good reason to believe that the economics of those cases will be similarly attractive to set IV.

Let us examine a few more uncertainties now. If, for example, escalation and electricity were only 1½ percent-per-year over inflation as has been suggested as a bottom number, then the $220 billion number for 8.8 million SWU's would be reduced to only $122 billion which is still an awfully big number.

The 3-percent case—a 3-percent escalation over inflation for electricity—would produce $176 billion. If, on the other hand, we were to assume, as has been assumed for the year of expenditure dollars for the program by the Department of Energy, a 9-percent-per-year escalation factor—in general, inflation—then the numbers are on the order of $190 and $249 billion, respectively. Those are incredibly large numbers which are difficult to think clearly of.

Then, we should perhaps consider another downside case and see if it still makes sense. One of those possible downside cases is where inflation goes on at 8 percent and power just does not escalate any faster than inflation. This might be possible even though nobody believes it.

If it did happen, then the cost difference on this same line would be reduced all the way to $75 billion. Or, as has been suggested by some people, let us assume that with no additional escalation over inflation for electricity that we made a factor of two error in the operating costs of GCEP, then that number is reduced to only $52 billion—still a very large number.

I have not addressed the time value of money much. As I said earlier, economists like to talk about that and talk about it in many different ways.

Last year I presented a very detailed paper to some of your staff, to Mr. Ottinger's committee, and many others in the Capitol Hill area, that presents six different ways of looking at the time value of money and the cost benefits of the gas centrifuge enrichment plan.

Probably the best one of those ways and a business-like way to look at them, is to look at a discounted cash flow internal rate of return basis and decide whether or not the project is a good deal on a strictly economic basis.

As I mentioned earlier, the numbers are very dependent on the assumptions that are made for future inflation. What I presented in that previous paper is a matrix of internal rate of returns. What it shows is that if inflation and electricity escalate at exactly the same rate—again, unlikely as I think we have agreed—then the deal is always 3 percent better than the inflationary rate. If electricity escalates at 4 percent higher than the rate of inflation then the deal is always as good as twice the inflationary rate. I do not know about you, but I would like to have a lot of my money invested where I was guaranteed, regardless of what inflation was, that my investment was always at least 3 percent better than inflation and, perhaps, twice what the inflation value is.

I address costs. and ways of treating costs and I feel compelled to remind myself and everyone else again, that the Government's operation of uranium enrichment is one of the most energy-intensive process industries in the world, absolutely. Also, the centrifuge offers a factor of 20 improvement in the energy intensity. Those are easy words to say but what do they mean?

The improvement that we are talking about here is unprecedented as an energy conservation measure in any of the industrial segments with which I am familiar. We are spending billions of dollars throughout industry today to gain improvement factors of 1.4 or less. The aluminum industry—1.25—is spending tens of billions of dollars planned over the next 20 years.

Of course, if 18, 25, or 30 billion kilowatt-hours of electricity are not important, and they may not be—I do not mean that facetiously, they may not be as important as they seemed to us a few years back—then that reduces the decision to one of pure economics. I think we have said enough about that.

I hope that it is clear from what I have said that I strongly support proceeding expeditiously to build the full 8.8 million SWU's of capacity. I think we should do that without delay. I believe the payoff for set IV is enormous. I further believe that the uncertainties and all of these payoff analyses that we have talked about here today are all on the side of making the project even more attractive as we go through time.

Let me suggest one thing to you in the way of thinking about discounted numbers that we like to talk about—numbers discounted back to today for some future project.

If we could turn the clock back to 1950 and sit here today and project that gasoline would be $1.30 per gallon in 1983 and discount that back to 1950, we would find that we are paying 3 cents per gallon more in 1983 than what we were paying in 1950—that would not have seemed like much to us then, would it? I do not know. I have not found any filling station that will take my 29 cents for gasoline if I try to assure him that it is actually a 1950 dollar with which I am dealing. At any rate, it is a difficult thing to cope with, but you always have to deal with, and spend dollars in the year you are living in, and that is what this analysis tells you about.

A few words about advanced isotope separation. I do not want anybody to think that I am not in favor of this. I encourage the development of AIS by whatever process is selected. I think that the process needs to be selected soon.

I do, however, I discourage decisions on GCEP which rely on the ultimate success and the accuracy of AIS costs and schedules. Those costs and schedules will not be met precisely as projected. As is characteristic of those kinds of technologies, at the present stage of development and it is unlikely to change in this case. It is a rare case in the world of technology where some improvements are not projected for the future and somewhere over the horizon. Technical progress and its benefits would be slow indeed if we always waited for the next technological breakthrough before we did anything.

A few minutes on revolving funds. I do not have time really to detail the discussions. I would love to and would be happy to do so at some other point in time.

Simply stated I support the initiatives that are in work. I support them wholeheartedly. I view them as important and very likely essential to any further step toward a businesslike operation of the uranium enrichment enterprise.

I believe the initiatives as I see them today will establish an important basis for whatever enterprise may follow on. They make an attractive way of measuring the success of the enterprise overall in the future, and send, in my view, one of the most important signals that we can to our customers: That we intend to operate in a businesslike way with continuity of purpose, and we are not here just for a while.

Thank you very much for your time and attention. I will be pleased to answer questions later.

Mr. VOLKMER. Thank you very much, Mr. Grant.

[The prepared testimony of Mr. Grant follows:]

## PREPARED STATEMENT OF RICHARD L. GRANT

I thank you for this opportunity to present information and views regarding the Department of Energy (DOE) Gas Centrifuge Enrichment Plant (GCEP) program. As requested, I will address my company's participation in GCEP along with my views of the program and my concerns about it. I will also give you my assessment of the option mentioned in your letter of invitation, i.e., limiting GCEP construction to two process buildings vs. eight; delay of GCEP schedule; or termination.

### BOEING PARTICIPATION

Boeing's participation in the Gas Centrifuge program includes the manufacture of centrifuge machines, value engineering and test for improved machine components, and R&D activities for Set IV and beyond Advanced Gas Centrifuges. After spending more than ten million dollars to perform early startup work in Seattle, Boeing has designed, constructed and equipped a factory specifically for centrifuge manufacture and R&D in Oak Ridge, Tennessee at a cost of over $60 million. This factory is in operation. The factory was planned and funded for Phase I production rates of about 50 per month and designed to flow easily into Phase II higher rate production in 1984 against a schedule provided by DOE with the original Request for Proposal(RFP) in mid-1979. The RFP required commitment of facilities, equipment and personnel for Phase I as well as a commitment to proceed into Phase II if selected. Boeing has complied with the requirement.

Boeing's factory in Oak Ridge employs about 300 people at present. Currently 250 have been hired from over 13,000 local area applicants, many of whom were unemployed. Phase II employment will be between 1500 and 1800.

### VIEWS OF THE PROGRAM

My views of the program are best described by reference to the facts cited below:

1. The existing P1C model of the centrifuge works as planned. Its output is equal to or better than projections. Its reliability in operation will be acceptable and those of us manufacturing them will make it even better.

2. The factor of 20 or more improvement in electric energy efficiency over the diffusion process is not speculative. One hundred metric tons of enriched uranium has been produced with the centrifuge.
3. After nearly $1 billion of total expenditures on the program, the costs have proven to be within one percent of the estimated costs on a month by month basis and are currently about one million dollars under.
4. Value engineering programs now in process will improve estimated life cycle costs by tens and perhaps hundreds of millions of dollars.
5. Means to increase individual machine and total plant output by the Advanced Gas Centrifuge are well developed, with high confidence of performance, will work and at modest additional costs.
6. 625 suppliers in 30 states are doing business with us supporting the program. Some have made capital investments specifically to supply the products.

In summary, the technology and cost effectiveness which attracted us to this program in the mid 70's looks even better today as project cost targets are met, as electricity costs continue to escalate, and as proven production capacity is in place and working.

## CONCERNS FOR THE PROGRAM

My concerns for the program are that continued slippage will make it impossible to continue to manage to the Total Estimated Cost (TEC) and that the lost opportunity for cost and energy savings are not given proper consideration. Further, I am concerned that the basis for decision making is obscured by tortuous comparisons and is unnecessarily related to demand uncertainty.

Let me address the demand question first. Certainly we must consider supply reliability, our international posture and cost competitiveness. However, the importance of the GCEP program and the motivation for proceeding toward the earliest possible operational date may be examined without presuming that demand will ever exceed the 8.8 million SWU capacity of the existing GCEP design or 13.2 million SWU for Set IV. Every year that these quantities of separative work are being produced without GCEP, between 18.9 and 28.3 billion more kilowatt hours of electricity are being paid for and consumed than would be necessary with GCEP. Therefore, assuming that these modest demands will continue to exist, rationale for GCEP may be decoupled from demand and treated, as it should be, for its worth as the means of producing its capacity while avoiding the cost and consumption of these quantities of energy.

If you will accept these conditions, then comparison of GCEP on an economic and conservation basis will be much simpler and the impact of any decisions regarding it made clearer.

Next, let's look at some simple and historically factual information on the cost of electricity. Since 1973 the cost of electricity for uranium enrichment has escalated an average of 20 percent per year or an average of about 10 percent per year over inflation. This aberration of about 9 years duration may be moderated in the future although the forces at work in our economy to cause significant moderation for any sustained time period are difficult to perceive. It has been suggested that electricity serving DOE enrichment plants should be expected to exhibit between one and one-half and three percent escalation higher than general inflation. My own assessment suggests that this factor will average at least four percent over inflation and the cost comparison data attached is based on that assessment. In any case, it is clear that both inflation and energy cost escalation must be expected. If we may ignore demand by assuming that it will always be as high as the capacity of GCEP, then we can make rational comparisons of the cost benefit of the centrifuge by simply determining the cost to produce the capacity of the GCEP over its lifetime and comparing that with the cost of producing the same capacity of gaseous diffusion over the same time period. If the difference in cost is a sufficiently large number to offset the capital costs, whatever method is chosen to deal with the time value of money, and any other uncertainties you may choose to assign to other parameters, then the net cost benefit is positive.

Referring to Figure I, the 8.8 million SWU GCEP case (using eight percent inflation and the four percent differential escalation for electricity) will result in an aggregate cost difference of about $220 billion. If only 2.2 million SWU capacity of GCEP were emplaced, the aggregate cost difference will be about $56 billion. As mentioned previously, the evidence of the expenditure of $1 billion to date with on-target performance suggests that the TEC predictions can be met. The TEC in Year of Expenditure (YOE) dollars for 8.8 million SWUs and assuming nine percent inflation is $10.4 billion (6.95B FY83 dollars) or $4.2 billion (3.7B FY83 dollars) for 2.2 million SWUs. Therefore, the important comparison for deciding between 8.8 million SWU capacity and 2.2 million SWU is the expenditure of an additional $6.2B YOE (2.75B FY83 dollars) compared to the additional cost avoidance of over $160 billion.

Next let's examine the value of the improved Set IV machine in this same context. If we can introduce Set IV in 1989 to the subsequent 6.6 million SWU capacity and retrofit into the first 2.2 million SWU capacity as appropriate, this would yield a total cost savings of about $320 billion or an additional $100 billion as shown in Figure II. My own estimate of the Set IV cost differential will not exceed one-half billion dollars including development costs. This payoff looks extremely attractive but only if demand is as high as 13.2 million annual SWUs.

Figure III shows similar cost savings data for future potential development of the Set V and Set VI centrifuges. The technology for these improvements does not require major breakthroughs. The costs estimates and the schedules for introduction for these further improvements are, however, uncertain as with all technology in the early stages of engineering development. There is, nonetheless, good reason to believe they will be similarly attractive.

Next let's examine uncertainties in these numbers. If for example the differential escalation in electricity were only 1.5% per year, the cost difference would be only $122 billion, or for a 3% per year case, it would be $176 billion based on 8.8 million SWU. If on the other hand inflation were to proceed as assumed for the TEC, these same cases would result in cost differences of $190 billion and $249 billion, respectively.

Finally let's examine cases where first, inflation proceeds at 8% but power does not escalate faster than inflation; and secondly, the same case but assuming we have made a factor-of-two error in the operating cost of GCEP. The corresponding total cost differences are $75 billion and $52 billion, respectively.

Once again I must remind you that the Government's operation of uranium enrichment is one of the most energy intensive process industries in the world and that the centrifuge offers a factor of 20 improvement in that energy intensity. This improvement is unprecedented in industry today. The private sector is spending billions of dollars to gain improvement factors of 1.4 or less. Of course if the savings of 18 billion or more kilowatt hours per year of electricity is not important, this reduces the decision basis to one of economics alone.

I hope it is clear from the foregoing that I strongly recommend continuation to emplace the full 8.8 million SWU capacity of GCEP and to do so without further delay. I also believe the payoff for Set IV development is very high and that confidence in its success should be high. I further believe that the uncertainties in the payoff are on the side of making the project even more attractive over the long run.

## ADVANCED ISOTOPE SEPARATION ACTIVITY

I encourage the development of AIS by whatever process is chosen in the near future but discourage decisions on GCEP which rely on the ultimate success and the accuracy of AIS cost and developmental schedules. It would be a rare case in the world of technology where some improvements were not projected for the future. Technical progress and its benefits would be slow indeed if we always waited for the next projected breakthrough.

## REVOLVING FUND

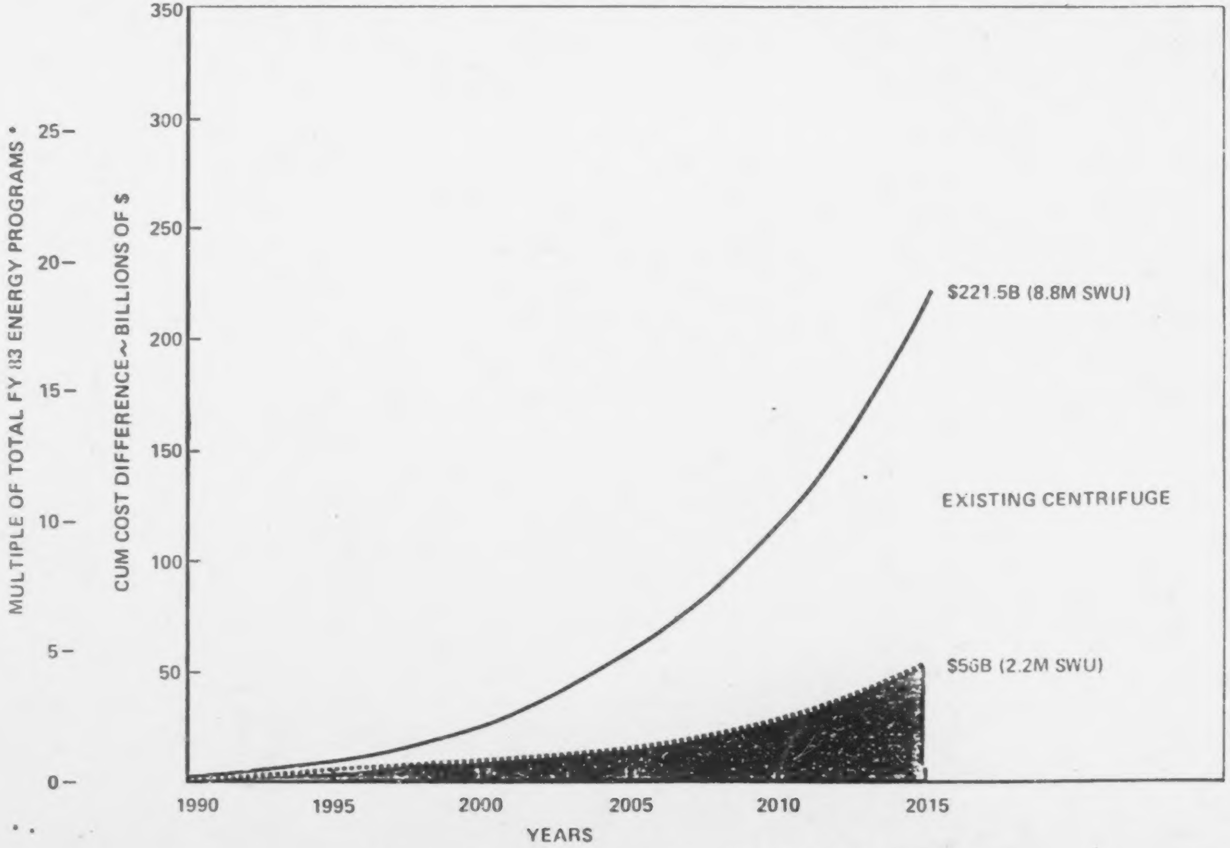
Time does not permit detailed discussion of initiatives to establish the revolving fund. Simply stated, I support these initiatives and view them as an important and very likely essential first step toward a businesslike approach to the entire enrichment enterprise. I believe it will establish an important basis for whatever other form the enterprise might ultimately take; it will provide an attractive direct means of measuring the success of the enterprise; and it will send an important signal to our customers that we intend to operate in a businesslike way with continuity of purpose.

I thank you for your time and attention. I will be pleased to address any questions you may have.

########

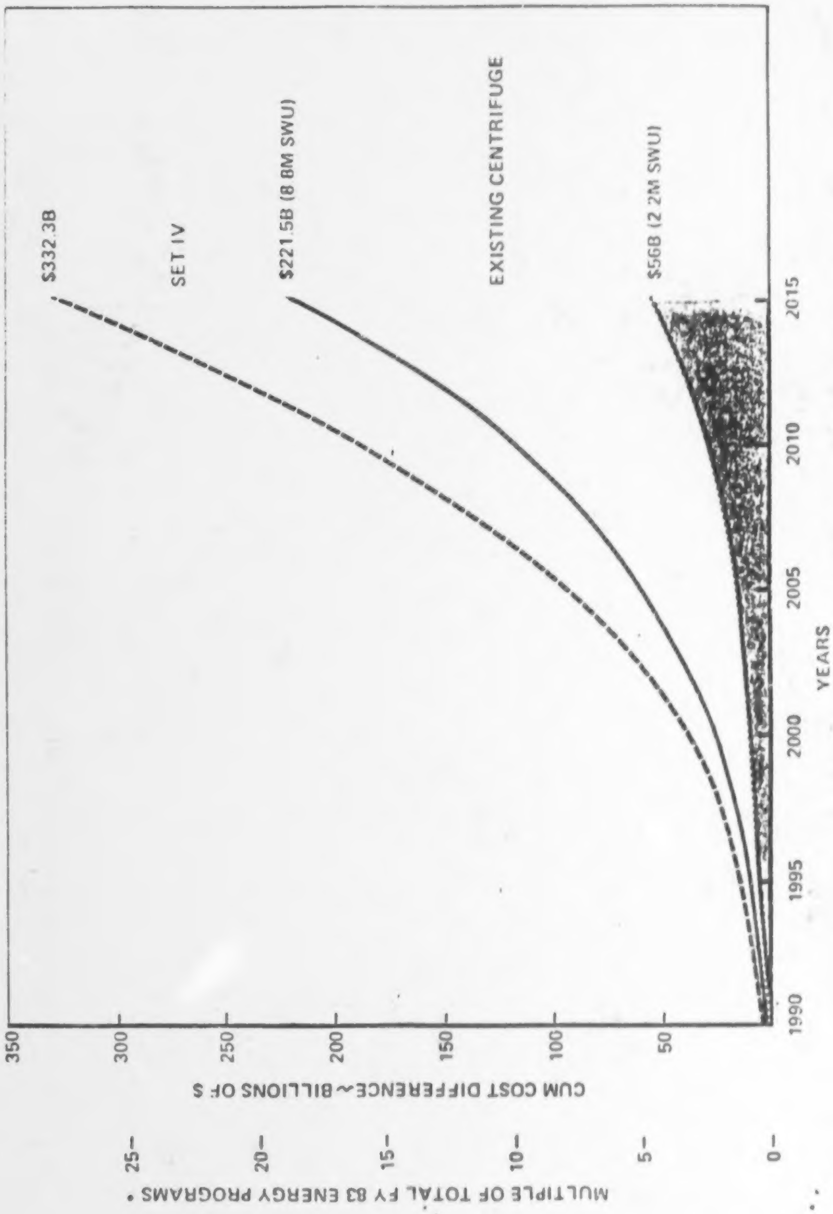
FIGURE I

COST SAVINGS FROM CENTRIFUGE OPTIONS



* INCLUDES $2.316B SPR AND $5.506B DEFENSE ACTIVITIES

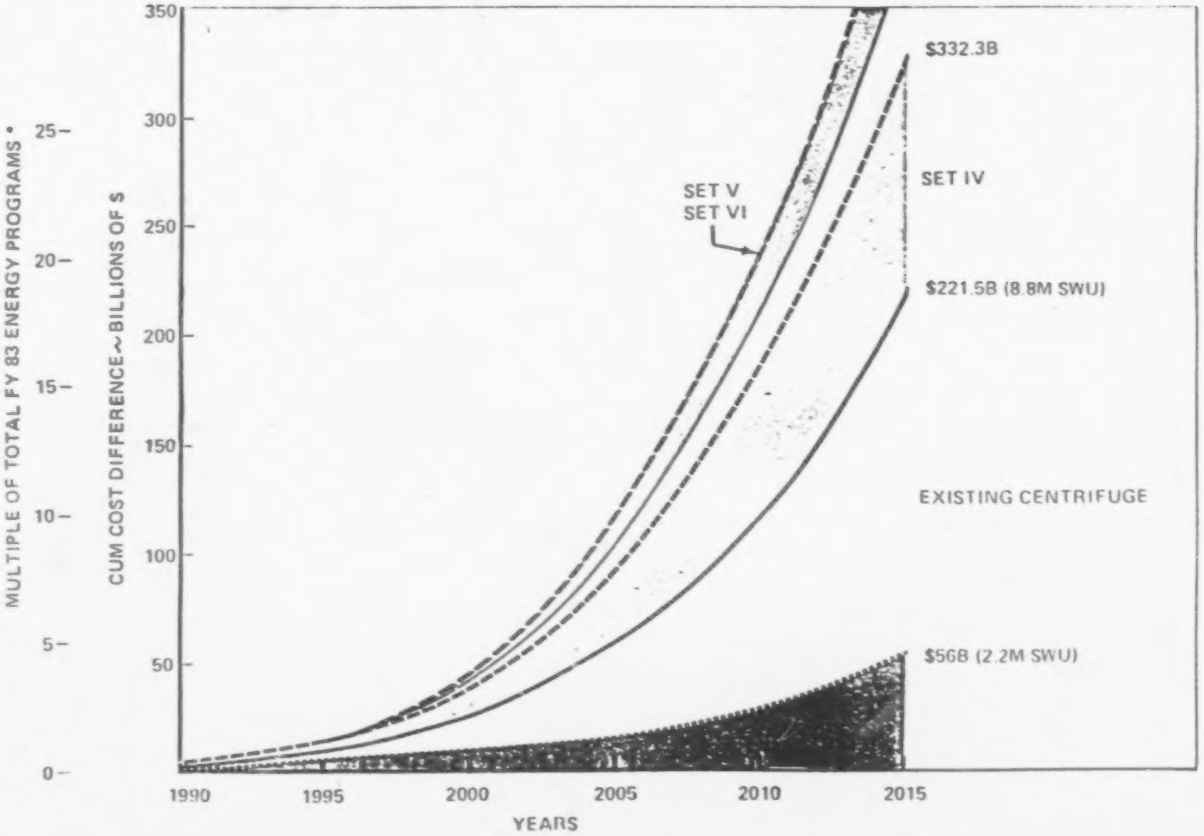
## COST SAVINGS FROM CENTRIFUGE OPTIONS



* INCLUDES $2.316B SPR AND $5.506B DEFENSE ACTIVITIES

FIGURE III

COST SAVINGS FROM CENTRIFUGE OPTIONS



* INCLUDES $2.316B SPR AND $5.506B DEFENSE ACTIVITIES

## RICHARD L. GRANT

Richard L. Grant is President and Chief Executive Office (CEO) for Boeing's wholly owned subsidiary, Boeing Engineering and Construction Southeast, Inc. (BECSI), located in Oak Ridge, Tennessee. He also serves as Executive Director and a member of the Management Committee for Boeing Engineering and Construction Company (BEC).

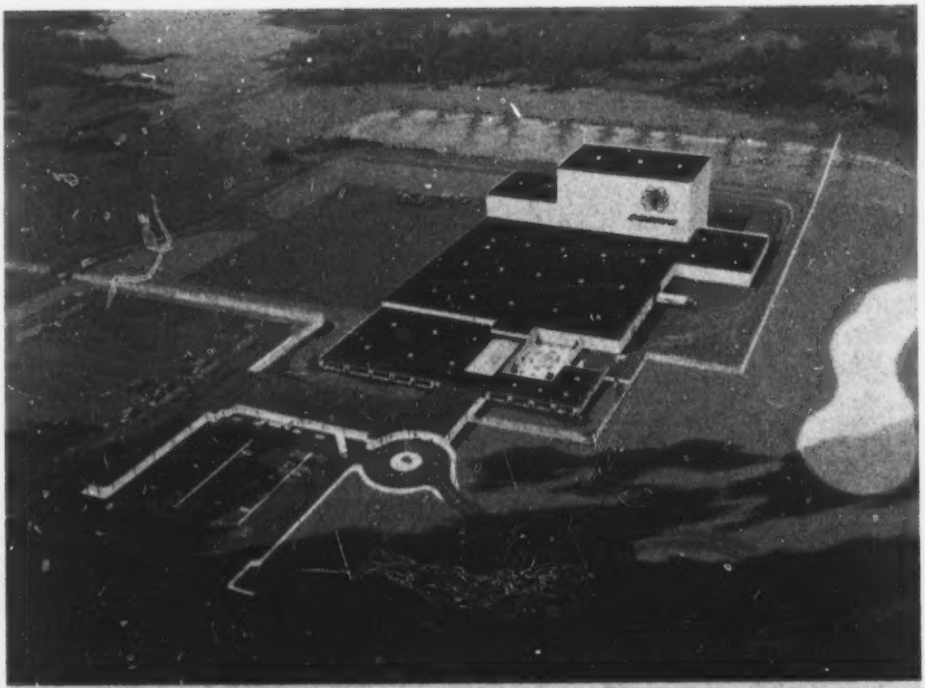
Mr. Grant has a B.S. in Aeronautical Engineering from the University of Illinois (1960) and is a graduate of the Executive Business Management Program at Cornell Graduate School of Business.

Mr. Grant joined Boeing, in February 1960, on the Minuteman Missile Program. For the next five years, he directed Dynamics, Stress, Loads, Rocket Motor Performance and Flight Test for development of the Minuteman Missile. This was followed by seven years managing structural dynamics, loads, stress, vibration, acoustics and test activities for the Minuteman underground systems.

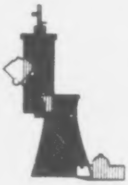
In March 1972, Mr. Grant was assigned to develop and direct programs which would utilize Boeing's aerospace technology, management systems and manufacturing resources in the Nuclear Power Industry. Since then, he has directed Boeing's efforts on the Reactor Safety Study (WASH 1400), the Clinch River Breeder Reactor, the Trojan Nuclear Power Plant, "N" Stamp manufacturing, Spent Fuel Casks and Transporter, Back-End of the Fuel Cycle projects - (Alternate Fuel Cycle Program ISRO, OWI Program Planning, and Global Spent Fuel Logistics Study), HTGR Commercialization, Nuclear Power Plant Modularization, and various other nuclear related projects.

Starting with Boeing's interest in private sector Uranium Enrichment in 1974, the Company's activities in Enrichment - both with private ventures and Department of Energy - were added to his responsibilities. Since the Boeing Corporate commitment in July, 1977 to pursue Centrifuge Enrichment, Mr. Grant has been assigned to devote 100% of his time to directing the Boeing Centrifuge Program.

Mr. Grant serves on Boards of Directors for The Bank of Oak Ridge, Roane-Anderson Economic Council, American Society of Engineering Management and the Cibola Corporation. He is also a member of Governor Lamar Alexander's Task force on Technology.

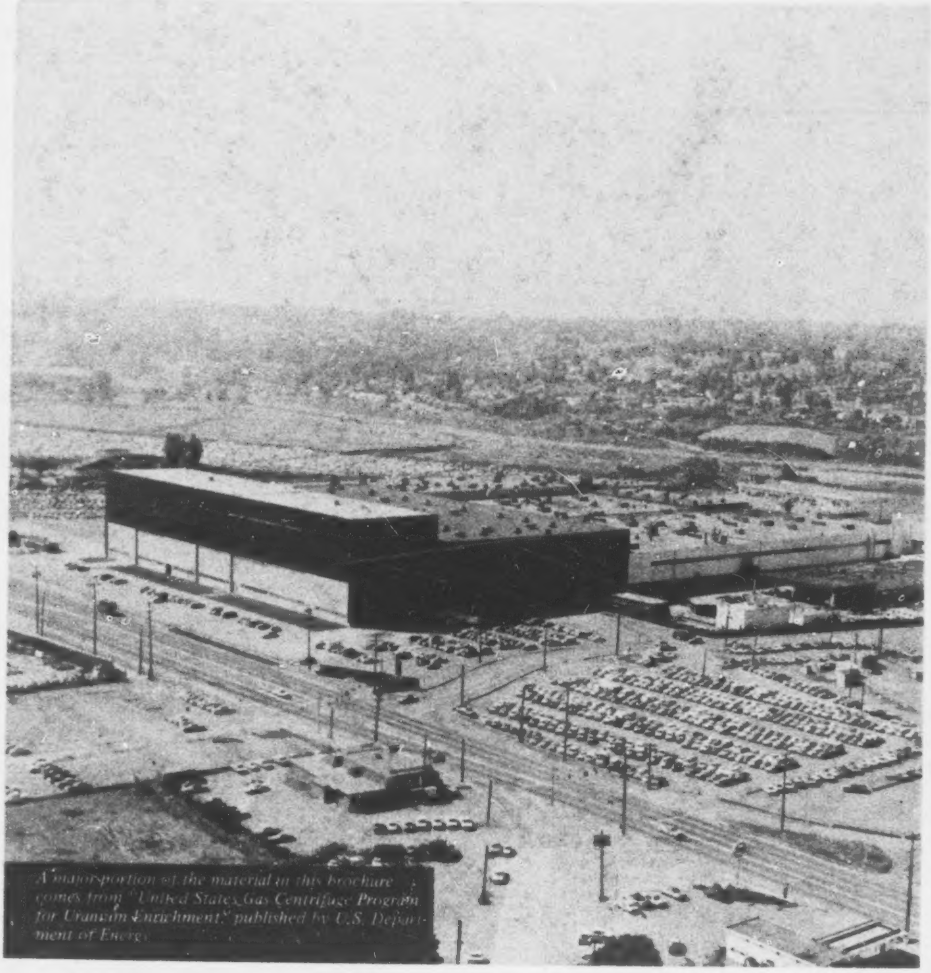


# Uranium Enrichment Program



*Cover*

*Artist's concept of Boeing Engineering and Construction's 45 million dollar manufacturing facility under construction in Oak Ridge, Tennessee. Ground breaking ceremonies were held September 22, 1979, for this 200,000 ft$^2$ factory dedicated to Phase I of DOE's Gas Centrifuge Enrichment Program.*



*A major portion of the material in this brochure comes from "United States Gas Centrifuge Program for Uranium Enrichment" published by U.S. Department of Energy.*

# Introduction

On September 12, 1979, Boeing Engineering & Construction and the Department of Energy signed a contract for BEC's participation in the first phase of the Gas Centrifuge Enrichment Program

This brochure gives the highlights of (a) what enrichment means, (b) how it is achieved, (c) a brief past, present, and future of this Government-controlled technology, (d) the expansion program at Portsmouth, Ohio, and (e) how BEC got into and plans to stay in this business.

# Uranium Enrichment

Uranium as found in nature consists principally of two forms of isotopes(1) $U^{235}$ and $U^{238}$. The $U^{235}$ isotope is fissionable, and this property of being able to split and give up heat makes it useful as a fuel in nuclear reactors. The $U^{235}$ isotope is only 0.711% by weight in natural uranium. Most of the nuclear power plants in the world today use uranium enriched to about 3% $U^{235}$ as fuel. A number of interrelated steps are involved in locating, preparing, using, and disposing of fuel for these reactors. Enrichment, the fourth step in the process, increases the concentration of $U^{235}$ from 0.711% to about the 3% required in nuclear reactors.

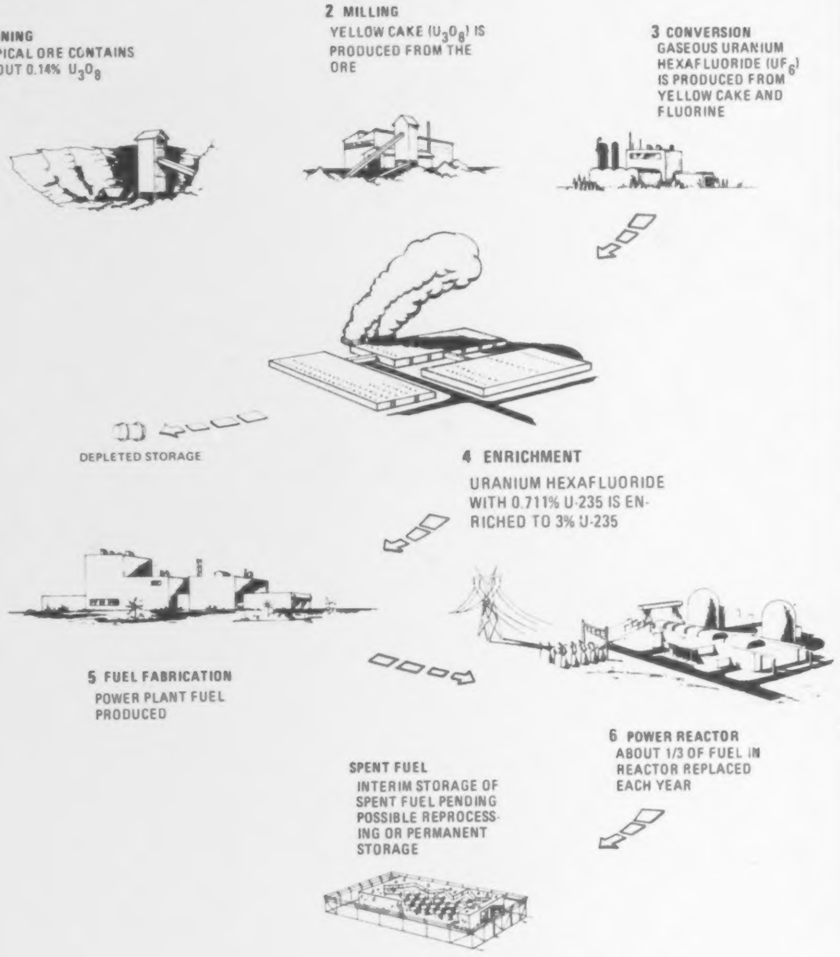
## U.S. Gaseous Diffusion Complex

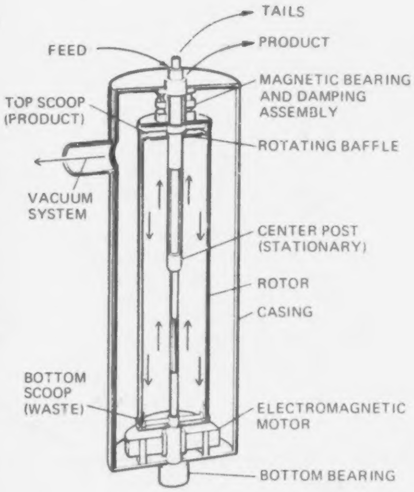
Almost all the world's current capacity to produce enriched uranium uses the gaseous diffusion process. The United States built the first gaseous diffusion plant at Oak Ridge, Tennessee, during World War II. Later the Oak Ridge plant was expanded, and two additional plants were built at Paducah, Kentucky, and Portsmouth, Ohio. Under direction of the DOE, the facilities at Oak Ridge and Paducah are operated by Union Carbide Corporation–Nuclear Division; the facility at Portsmouth by Goodyear Atomic Corporation. A $1.5 billion improvement and uprating program is now in progress to increase the total capacity of these plants by 60% to about 27 million SWU(2) per year.

(1) Isotopes are atoms of the same chemical element, very similar in chemical behavior but distinguishable by radioactive transformations, differences in atomic weight, and other physical characteristic variations.

(2) A separative work unit (SWU) is a measure of the effort expended in a uranium enrichment plant to separate uranium of a given $U^{235}$ content into two components, one having a higher percentage of $U^{235}$ and one having a lower percentage of $U^{235}$.

# Nuclear Fuel Cycle


1 MINING
TYPICAL ORE CONTAINS ABOUT 0.14% $U_3O_8$
2 MILLING
YELLOW CAKE ($U_3O_8$) IS PRODUCED FROM THE ORE
3 CONVERSION
GASEOUS URANIUM HEXAFLUORIDE ($UF_6$) IS PRODUCED FROM YELLOW CAKE AND FLUORINE
DEPLETED STORAGE
4 ENRICHMENT
URANIUM HEXAFLUORIDE WITH 0.711% U-235 IS ENRICHED TO 3% U-235
5 FUEL FABRICATION
POWER PLANT FUEL PRODUCED
6 POWER REACTOR
ABOUT 1/3 OF FUEL IN REACTOR REPLACED EACH YEAR
SPENT FUEL
INTERIM STORAGE OF SPENT FUEL PENDING POSSIBLE REPROCESSING OR PERMANENT STORAGE



**Interior of a Centrifuge** *is shown in this cutaway drawing. The thin-walled rotor is driven by a small electromagnetic motor attached to the bottom of the casing. The top end of the rotor is held in a vertical position by a magnetic bearing and does not touch stationary components. Gas is fed into and withdrawn from the rotor through the stationary center post, which holds three concentric tubes for the feed, the product, and the tails. The stationary bottom scoop protrudes into the spinning gas and provides a mechanical means for driving the vertical flow of gas. The top scoop, which serves to remove the enriched product, is protected from direct interaction with the rotating gas by the baffle, which has holes allowing the enriched gas to be bled into the area near the scoop. The baffle is needed to keep the top scoop from imposing a vertical flow that would counteract the crucial one generated by the bottom scoop.*

# Gas Centrifuge Process

Dr. Jesse W. Beams of the University of Virginia first demonstrated an operating centrifuge in 1934. The degree of enrichment in a single centrifuge machine is dependent on the mass difference of the isotopes being separated, the length of the rotor and most importantly the peripheral speed of the rotor. In large, high-speed machines it is possible to obtain a degree of enrichment many times that of a diffusion stage. The principle of a gas centrifuge is illustrated at left. Gaseous uranium hexafluoride ($UF_6$) is fed into a rotor that spins at high speed inside an evacuated casing. The gas accelerates to nearly the speed of the rotor. Centrifugal force causes the heavier $U^{238}$ molecules to move closer to the wall of the rotor, producing partial separation of the $U^{235}$ and $U^{238}$ isotopes. This separative effect is increased by an axial countercurrent flow of gas within the centrifuge. Feed is introduced near the middle of the rotor, and enriched and depleted streams are removed near the ends.

The desired enrichment is not obtained in a single centrifuge so machines must be connected in a series known as a stage. The stages (feed, enriching, and stripping) are then connected to form what is known as a cascade. Only a small amount of gas will flow through a single centrifuge. Therefore, a large number of machines must be connected in parallel to achieve the total flow necessary for a single stage of enrichment in a large-capacity plant.

Perhaps the most significant difference between the gaseous diffusion and gas centrifuge processes is power usage. A centrifuge plant requires only about 5% of the power needed for a diffusion plant of equivalent capacity. For a plant of 8.8 million SWU per year capacity, about 2,700 megawatts (MW) of electrical power would be required for a diffusion plant, and only about 135 MW for a centrifuge plant. In addition to the energy saved by this lower power demand, corresponding environmental benefits result from lower demands on water resources for cooling.

# Current Centrifuge Program

By the end of the 1960's, results from the U.S. centrifuge program had established the potential attractiveness of the gas centrifuge process. The scope of the program has been systematically expanded to ensure capability in all areas essential to the eventual construction and operation of a production-scale facility. Major areas of the current program include:

*Basic studies–continue the study of centrifuge theory*

*Machine development–in separative capacity, safety, and efficiency of machines*

*Reliability–determine the nature and frequency of machine failures*

*Producibility–Develop methods of producing high-capacity, high-reliability machines at low cost*

*Operability–demonstrate the operation of the centrifuge process on a large scale*

*Engineering and constructibility–develop and refine plant criteria and construction methods for a production enrichment plant and supporting assembly and recycle facilities*

Since early in the program, Union Carbide and AiResearch have worked concurrently on centrifuges of independent design. By 1976, both organizations had developed high-capacity, efficient, and reliable machines. A key action taken early in 1977 was the selection of a single design to be developed by both organizations for ultimate use in the full-size enrichment plant.

All phases of the current and future program have been coordinated in a comprehensive 10-year plan to ensure availability of machines and plant technology.

### Gas Centrifuge Development Facilities

Several development facilities have been or are being constructed to improve centrifuges, associated equipment, and operating procedures. AiResearch at Torrance, California, operates machine development, machine production, and test facilities as a Government contractor. The University of Virginia has limited development facilities; and the remaining facilities are operated by Union Carbide at Oak Ridge Tennessee. Lawrence Livermore Laboratory and Los Alamos Scientific Laboratory provide support by developing hydrodynamic flow models. BEC is currently providing development support to AiResearch in Torrance, California, and Union Carbide in Oak Ridge, Tennesse, as well as R&D on new materials in Seattle.

The Equipment Test Facility (ETF) began operation in 1971 to examine the reliability of four types of high-capacity centrifuges. Reliability testing is continuing on some of these earlier machines.

Completed in 1974, the Component Preparation Laboratories (CPL) at Oak Ridge and Torrance were built to aid the development and demonstration of techniques for manufacturing centrifuges, and to reduce the time and cost of the manufacturing process. These manufacturing techniques are being provided to private industry.

The Component Test Facility (CTF), for which Boeing is fabricating centrifuge rotors, began initial operation in 1975, and is used to test the reliability and operability of substantial numbers of centrifuges. This facility serves as a pilot plant cascade. Although a test facility, the CTF has a production capacity of about 50,000 SWU per year.

The Advanced Machine Development Laboratories (AMDL), for improving and testing centrifuges, are located at both Oak Ridge and Torrance.

The Advanced Equipment Test Facility (AETF) began operation in early summer of 1978. This facility will be used primarily to test the reliability of the production centrifuges that will be used in the Centrifuge Plant Demonstration Facility (CPDF) and the full-size Gas Centrifuge Enrichment Plant (GCEP). The facility will also be operated to test plant subsystems.

### Centrifuge Plant Demonstration Facility

The CPDF is important to BEC. This facility that was planned to establish procurement sources is scheduled to be in operation by early 1982 at a cost in excess of $60 million. The first 50 machines to be delivered during the Phase I contract are for this facility. The other two centrifuge manufacturers

(CM's) will also have machines operating in the CPDF so direct comparison between suppliers will be in effect.

The Centrifuge Plant Demonstration Facility will also test cascading equipment and systems. Although the technology was previously under DOE control, all of the equipments and all machines will be produced by industry.

On July 13, 1978, Boeing was awarded the contract to supply the service module for the Centrifuge Plant Demonstration Facility. The service module provides the processes, utility, and auxiliary piping and valving plus electrical controls for the centrifuge operation.

The facility will be used to obtain information to show that producible machines and the necessary industrial vendors are available, and that the design, construction, and operating criteria are satisfactory for use in the full-size plant.

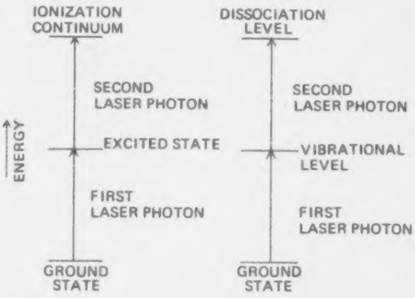
As testing of machine and cascade auxiliary equipment in the CPDF proceeds, further extensive evaluation and qualification of industry-produced machines and plant components will be conducted to achieve cost and performance goals. These activities will demonstrate machine producibility and operability by the manufacture and testing of machines and plant components in Government facilities, and by early operation of the first GCEP production train, which consists of six cascades. Machines and plant components beyond the CPDF may incorporate improvements from the development program.

**Advanced Isotope Separation**

In the future, the U.S. uranium enrichment capacity is expected to be bolstered by one or more of the three Advanced Isotope Separation (AIS) processes now under development at the Los Alamos Scientific Laboratory, Lawrence Livermore Laboratory, and TRW. These processes promise greater energy efficiency, high capital incentives, and a means to extend our uranium reserves by economical conversion of our vast stockpiles of uranium "tails" to feed-equivalent assays for reuse in diffusion and centrifuge facilities.

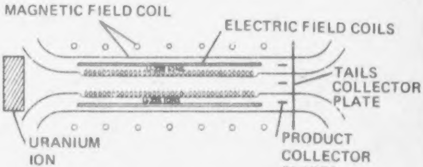
At the Lawrence Livermore Laboratory, scientists are working on the Atomic Vapor Laser Isotope Separation (AVLIS) process. Here, atomic uranium vapor is illuminated by precisely tuned monochromatic laser light to selectively excite and ionize the $U^{235}$ atoms. This process, called photo-ionization, is illustrated below. Once ionized, the positively charged $U^{235}$ atoms are extracted from the neutral $U^{238}$ atoms by an electrically biased collector.

A similar process involving lasers is under development at the Los Alamos Scientific Laboratory where gaseous uranium hexafluoride, $UF_6$, is used in the Molecular Laser Isotope Separation (MLIS) process. The principle of MLIS is also illustrated below. Precisely tuned laser light is absorbed only by the $UF_6$ molecules containing $U^{235}$ atoms. This addition of energy in the molecule causes one of the fluorine atoms to become liberated in a process called photo-dissociation. The newly formed $UF_5$ molecules exist as an aerosol in the gaseous $UF_6$ and are collected mechanically.



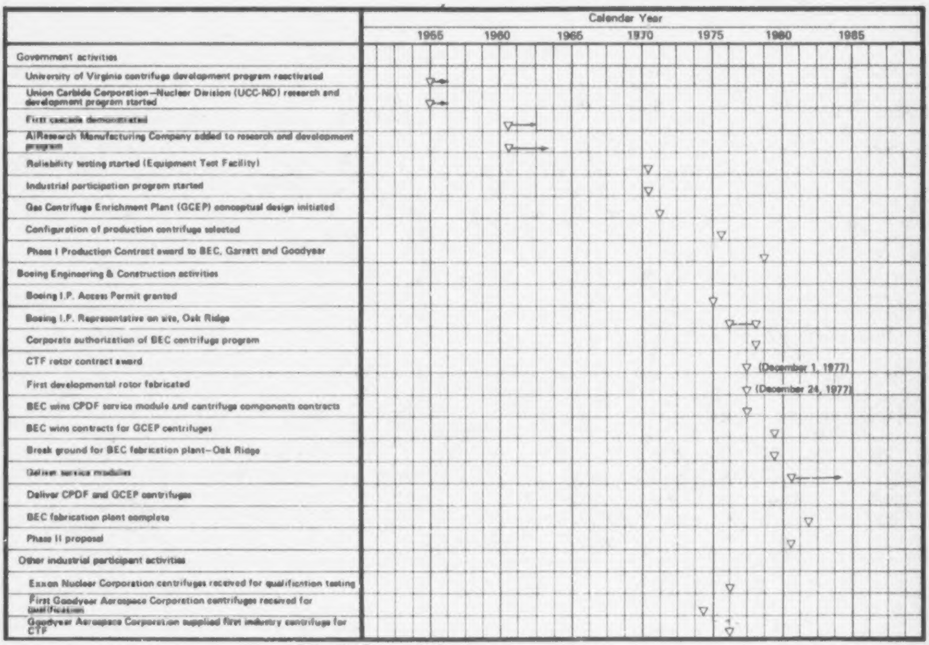
*Resonant excitation is achieved by laser photon absorption by the $U^{235}$ atom or the $U^{235}$ containing molecule initially in the ground state where isotopic energy states are most different. A second photon completes the process of photo-ionization of the atom or photo-dissociation of the molecule. The ions are collected electromagnetically and the new molecules are collected mechanically.*

TRW's Plasma Separation Process (PSP) differs fundamentally from the AVLIS and MLIS processes. The principle of the PSP is illustrated at right. A mixture of $U^{235}$ and $U^{238}$ atoms and electrons, called a plasma, travels through a uniform magnetic field. The ions orbit the lines of the magnetic field at a frequency inversely proportional to their mass. This frequency, called the ion cyclotron frequency, differs for each uranium isotope. An electric field that oscillates in resonance with the $U^{235}$ ion cyclotron frequency transfers energy to the $U^{235}$ ions, increasing their orbital radii. An array of slats is configured to intercept these $U^{235}$ ions while allowing the majority of the $U^{238}$ ions to pass through.



*A plasma separation process schematic. The orbital radii of the $U^{235}$ ions increase as they gain energy from the electric field, which pulsates in resonance with the $U^{235}$ ion orbit rotation or cyclotron frequency. The $U^{238}$ ions rotate at a different frequency and are not affected. The $U^{238}$ ions then pass through the "product" states and condense out on the "tails" collector plate.*

# Historical Program Activities

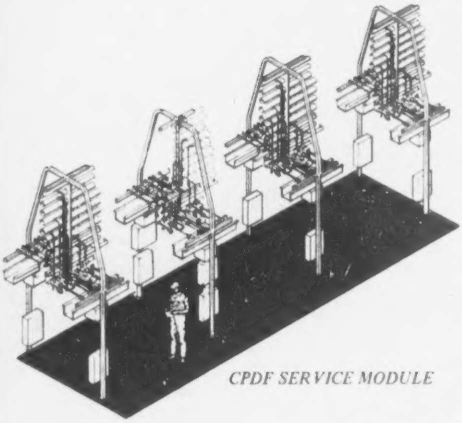


# Service Module

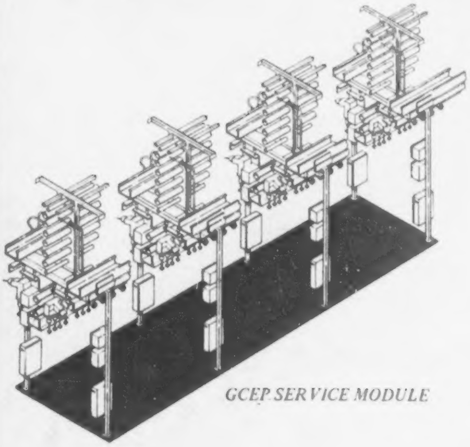
The production enrichment (GCEP) add-on plant at Portsmouth includes thousands of machines connected in cascades and trains. It therefore lends itself to modular designed service hookup. In this arrangement feed material is fed to each machine, tails and enriched material or product are transferred out of each machine. Machines are also connected so that continuous enrichment and continuous depletion of the $U^{235}$ isotope takes place, until desired products and tails are attained. The module consists of: feed header, product header, tails header, vacuum headers, cooling water machine drive power, instrumentation, lighting facilities and all of the necessary cables, valves, and branch tubes that connect the headers to machines.

Some of the important requirements are: very high quality weldments, close tolerance valve locations, cleanliness and leak tightness. Another important feature of this 45 ft long and 6 ft wide assembly is that the structural legs telescope to facilitate shipping. The service module installed reaches 12 ft.

BEC will deliver the first CPDF service module early in 1980. The request for proposal for the GCEP modules is expected before the end of the year. The total sales are projected to be about $500 million, in current dollars over several years.



*CPDF SERVICE MODULE*



*GCEP SERVICE MODULE*

# Gas Centrifuge Enrichment Plant

The Gas Centrifuge Enrichment Plant will be a large construction project. It is designed to provide a nominal 8.8 million SWU per year of separative capacity and will consist of eight process buildings, plus auxiliary, administrative support, test, and service buildings. The total area under roof is about 90 acres, and each process building would conveniently hold four football fields. The project will require new industrial manufacturing capacity as well as the talents of a number of architect-engineers and construction contractors.

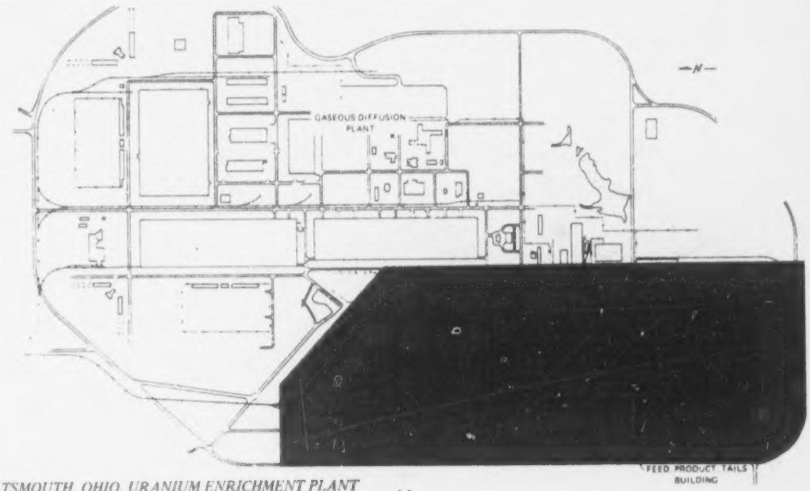
**Site**

The Department of Energy directs extensive uranium enrichment operations at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. To locate the centrifuge enrichment plant at one of these existing sites provides advantages of shared facilities, administration, and overhead. These considerations entered into the selection of the Portsmouth site, which is operated for the DOE by Goodyear Atomic Corporation. The construction site at Portsmouth consists of about 300 acres of relatively level land lying west and south of the existing diffusion plant.

**GCEP Design**

Design of the Gas Centrifuge Enrichment Plant is the outgrowth of conceptual engineering design studies that began in 1973 as an enrichment planning contingency measure.

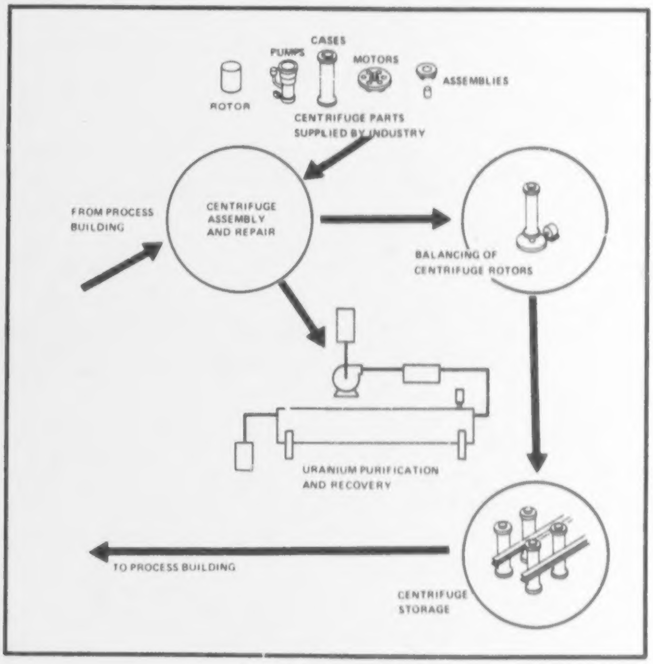
The conceptual studies have been performed by Union Carbide Corporation–Nuclear Division and two architect-engineering firms, Catalytic, Inc. (Philadelphia), and Commonwealth Associates (Jackson, Michigan), with contributions by AiResearch, the University of Virginia, and industry. This effort has provided preliminary design of buildings, equipment and support systems, improved design for major pieces of equipment, construction schedules, and estimates of construction and operating costs. In December 1975 a complete, conceptual design and cost estimate of a full-size gas centrifuge plant (about a million SWU per year) was completed.



*PORTSMOUTH, OHIO, URANIUM ENRICHMENT PLANT*
*The gas centrifuge plant is highlighted at the bottom right.*

### Recycle/Assembly Facility

The Recycle/Assembly facility (R/A) is one of the key areas in the plant. The facility will first be used to assemble and test the initial complement of centrifuges. When the plant is in operation, failed centrifuges are transported to the area, and the cause of failure is diagnosed. Repairs are made, rotors are rebalanced or replaced, and the machines are made ready for return to service. Used parts are decontaminated, and the liquid effluent is processed to recover the uranium. In addition, spare parts are received and checked in the R/A area. The efficient operation of this facility continues to be an area of intensive study. Figure comparing the most important characteristics of each process is shown below.


CASES
PUMPS
MOTORS
ROTOR
ASSEMBLIES
CENTRIFUGE PARTS SUPPLIED BY INDUSTRY
FROM PROCESS BUILDING
CENTRIFUGE ASSEMBLY AND REPAIR
BALANCING OF CENTRIFUGE ROTORS
URANIUM PURIFICATION AND RECOVERY
TO PROCESS BUILDING
CENTRIFUGE STORAGE

*Recycle and assembly flow*

# Centrifuge Plant Expansion

On August 2, 1979, DOE selected three industrial firms for the initial manufacture of gas centrifuge machines for the Centrifuge Production Demonstration Facility (CPDF) and the Portsmouth Gas Centrifuge Enrichment Plant (GCEP). The three organizations selected are:

Boeing Engineering & Construction Company, Seattle, Washington

The Garrett Corporation, Inc., Los Angeles, California

Goodyear Aerospace Corporation, Akron, Ohio

Machine procurement will be conducted in two phases:

Phase I will involve the qualification and furnishing of machines for the CPDF and the first complement of machines for the GCEP (including the first train of six cascades). In addition, engineering and manufacturing studies associated with centrifuge production will be conducted in the course of the next year. This phase will be performed under cost-type contracts, with a total estimated cost of $235 million (compared to DOE's earlier estimates of $150–300 million).

Phase I contract negotiations began August 8, 1979. These negotiations resulted in contracts being signed on September 12–14, 1979 with Boeing, Garrett, and Goodyear. These contracts cover all details of the Phase I contractor responsibilities for qualification and provision of centrifuge machines and components.

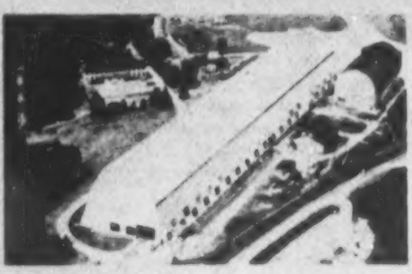
Phase 2 will involve the production of the balance of the machines for GCEP. DOE now contemplates executing fixed-price contracts with two of the three Phase 1 contractors for this longer range procurement. The estimated cost of Phase 2 is currently estimated at $1 billion in today's dollars.

DOE reports that major GCEP facility designs are targeted for completion in mid-1982. As of October 1979, design status was:

| [illegible] | [illegible] | [illegible] |
|---|---|---|
| 1. Support facilities and Site Preparation | Catalytic, Inc. | 39 |
| 2. Process Facilities | Fluor Engineers and Construction, Inc. | 24 |
| 3. Recycle and Assembly | Bechtel, Inc. | 32 |
| 4. Electrical Distribution Systems | Commonwealth Associates | 70 |

*PLANT EXPANSION SCHEDULE STATUS*

Garret has leased facilities in Sandusky, Ohio



**Boeing Engineering and Construction**

*Gas centrifuge machine manufacturing equipment and test facilities have been installed in the northeast corner of building [illegible]101 at the Developmental Center (75,000 ft²)*

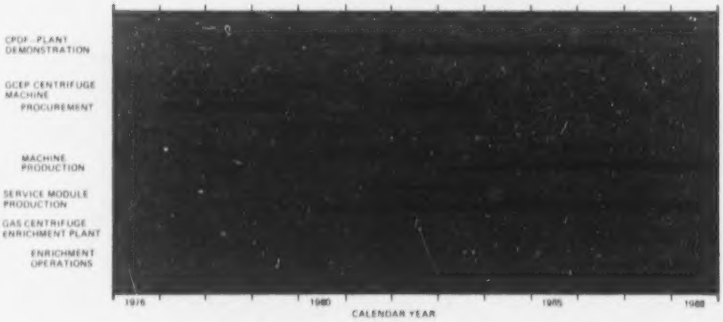
*(Insert) Artist's concept of Boeing Engineering & Construction's $45M manufacturing facility under construction at Oak Ridge, Tennessee*

**Goodyear Aerospace Corporation**

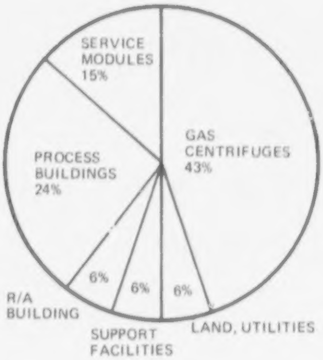
*Gas centrifuge machine manufacturing equipment, test facilities, and an advanced technology development laboratory have been installed in this airship hangar located at Wingfoot Lake near Akron, Ohio.*

## GCEP Milestones

*Key milestones are phased to permit an orderly and technically sound building-block approach to plant construction and initial operation. Startup of process production buildings is planned as centrifuges are installed and checked out. Initial production is planned for CY 1986 and full production in CY 1988 for the first of 8 process buildings.*



## GCEP Major Elements



| | |
|---|---|
| **BEC Interest** | |
| Centrifuge production | $1.5 Billion |
| Service module production | 0.5 Billion |
| Other (development, support, etc.) | 0.2 Billion |

**BEC Strategy**

$1 Billion + total contracted for GCEP

Follow-on replacement hardware value to BEC ≈ $2.2 Billion.

## Major GCEP Procurement

The GCEP program involves a number of the business segments in the U.S. A break down of the equipment procurements is shown at the right. UEP interest in the machines and modules was noted earlier.

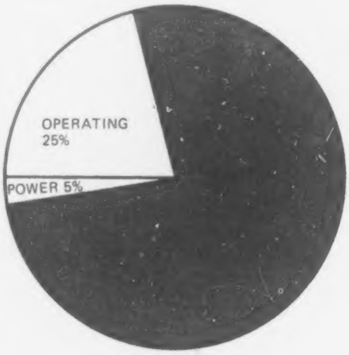
| | |
|---|---|
| Centrifuge machines | $ 1.7 Billion |
| Service modules | $ 500 Million |
| Isolation valves | $ 100 Million |
| Machine variable instrument package | $ 30 Million |
| Machine drive package | $ 40 Million |
| R/A–rotor balancing system | $ 12 Million |
| R/A–material handling | $ 10 Million |
| R/A–test systems | $ 6 Million |
| Assay mass spectrometers | $ 5 Million |
| Master data acquisition system | $ 12 Million |

## Cost of Separative Work

$75/SWU

The Department of Energy has estimated the economics of uranium enrichment for the Portsmouth gas centrifuge plane. In fiscal year 1980 dollars, the capital cost for the plant is $5.1 billion. Annual operating costs and power costs are estimated to be 170 and 3.5 million, respectively. These costs result in a price of $75 per SWU. The chart at left, shows the percentage breakdown among capital, including interest during construction, power, and other operating costs.

The current DOE calculation of separative work price is based on full cost recovery over the three-site enrichment complex. This policy provides that additional costs such as the cost of Government feed and imputed interest on (1) Government investment and (2) on the separative work component in the enriched product inventory will be reflected in the final separative work price. As construction on the Portsmouth gas centrifuge plant progresses, its costs will be factored into the DOE pricing calculation.



*Cost Estimate for Separative Work from Centrifuge Enrichment Plant*

# Keeping The Business Won

After the tremendous effort, experience gained and important successes noted, and with complete commitment by the Boeing Company, increasing the scope of this business is vital to UEP-BEC growth. We intend to continue our successful ways by:

Keeping DOE program on track

Maintaining quality manufacturing credibility

Producing at lower than predicted costs on schedule

Innovating producibility improvements
    Company funded
    DOE funded

All of the above resulting in a winning bid on Phase II

BOEING ENGINEERING & CONSTRUCTION
SOUTHEAST INCORPORATED

# SUPPLIERS

JUNE 1, 1981

## WASHINGTON

[illegible]

## WASHINGTON (CON'T)

[illegible]

## WASHINGTON (CON'T)

[illegible]

## CALIFORNIA

[illegible]

## CALIFORNIA (CON'T)

[illegible]

## ILLINOIS

[illegible]

## INDIANA

[illegible]

## KENTUCKY

Huntington Alloys, Inc.
Parker Seal
Sargent & Greenleaf
Shelton Metrology Laboratories

## KANSAS

C. Tennant

## MARYLAND

Security Engineered Machinery

## VIRGINIA

American Hofmann Corp.
Bethlehem Corp.
I.E. R. Johnson Assoc.
Teledyne Hastings

## WISCONSIN

Allen-Bradley, Inc.
Cooper, Inc.
C&H Distributors
Enerpac, Inc.
Johnson Service, Inc.
MG Cutting Systems Div.
Milwaukee Electric Tool Corp.
Wilson Inst. Co.
Tab Products Co.

## ARIZONA

Gilbert Labs
Jensen Tools and Alloys

## ALABAMA

Hobart Refrigeration
John Fluke Co.
Sargent Welch
Whiting Corp.
Wright Line

## NORTH CAROLINA

Coffing Hoists
Crowder Steel Co.
Kewaunee Scientific Equipment Corp.
Lummus, Inc.
Measurements Group
R.E.A. Business Equipment Co.

## SOUTH CAROLINA

Sumpter Machine Co.

## FLORIDA

Aeroplex Corp.
B&D Industrial Supply
Bushwell Electric Co.
Construction Steel Drum
Diecraft
F.W. Bell, Inc.
National Partitions, Inc.

## MINNESOTA

Despatch Industries
Di-Acro Division Houdaille Industries
Kurley Associates, Inc.
3M Company

## MISSOURI

Bolder Grinders
McDonnell Douglas Automation

## MISSISSIPPI

Sound & Communications

## NEW HAMPSHIRE

Digital Equipment Co.
Modular, Inc.
Sorbus Co.

## COLORADO

Hach Chemical Corp
Kaman Sciences Corp

## VERMONT

Bryant Grinder Division Ex-Cell-O Corp.
Challenge Machinery Company
Jones and Lamson Products
Rock of Ages, Inc.

## RHODE ISLAND

Federal Gage Co.
Snead, Inc.
Taft-Peirce Co.

## DELAWARE

Process Instruments Division E.I. DuPont

## IOWA

The Fisher Meter Co.
Thermodyne Corp.

## SOUTH DAKOTA

K.O. Lee Company

## UTAH

American Metals

## NEVADA

Bently Nevada Corp.

## DISTRICT OF COLUMBIA, WASHINGTON

Doug & Manning
International Energy Associates

## OREGON

Air Oil Products, Inc.
Electronic Controls Design
Fabes Machinery Co.
Familian Northwest, Inc.
George Bethell, Inc.
Hewlett/Packard
Microsemi, Microwave, Inc.
Nanmac Corp.
Northwest Machine
Norwest NDT, Inc.
Tektronix

## TEXAS

Augat, Inc.
Dresser Industries
Emmett Hamaker
Instec, Inc.
Kewaunee Scientific Equipment Corp.
Lighthouse For The Blind
Organic Products Company

## CONNECTICUT

Associated Spring
Aeronautics Industries, Inc.
Borden Corp.
Branson Sonic Power Corp.
Cushman Chucks
Dexter Corporation
Edmunds
Hewer Electronics
Martin Building Products
Omega Engineering, Inc.
Pratt & Whitney Machine Tool Division
Perkin Elmer
Rogers Electric Co.
Revere Corp of America
Shuster Grinder Co.
Super Winch, Inc.

## PENNSYLVANIA

[illegible]

## TENNESSEE

[illegible]

## TENNESSEE (CON'T)

[illegible]

## OHIO

[illegible]

## MICHIGAN

[illegible]

## MASSACHUSETTS

[illegible]

## NEW JERSEY

[illegible]

## NEW YORK

[illegible]

## GEORGIA

[illegible]

Mr. VOLKMER. Before we proceed with Mr. Clark's testimony, I would like to recognize the gentlelady from Tennessee, chairman of the subcommittee, for a brief statement.

Mrs. BOUQUARD. Thank you very much, Mr. Volkmer. I thank you for chairing the hearings today. You always do a good job. For those of you who do not know, Mr. Volkmer is one of our most conscientious members. He not only makes an effort to be present at all the hearings but he has toured so many of our facilities. I am certainly proud to call him my colleague and have him chair these hearings today. This is my eighth year here and it is the first time I have had car trouble getting to work so I guess that is not a bad record.

We are awfully happy to have all our witnesses here today. Thank you very much for being here. In addition to Mr. Grant, we also have another resident of the Third Congressional District of Tennessee, Dr. Bob Merriman, director of enrichment and technology at Union Carbide.

I want to welcome all of you and thank you very much for your testimony.

Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you, Madam Chairman.

I just wish to say that it has been a pleasure for me to serve under your leadership on this committee and I appreciate your information and advice on many issues.

At this time I would like to recognize Mr. Clark for his statement. Your full written testimony will be included in the record.

## TESTIMONY OF ROBERT W. CLARK, PRESIDENT, GOODYEAR AEROSPACE CORP., ACCOMPANIED BY JOHN C. FELDSCHER, MANAGER, BUSINESS AND ECONOMICS, GOODYEAR AEROSPACE CORP.

Mr. CLARK. Thank you, Mr. Chairman.

I am Robert Clark, president of the Goodyear Aerospace Corp. which is a wholly owned subsidiary of the Goodyear Tire & Rubber Co.

We are that Goodyear corporate entity engaged in the manufacture of centrifuges for uranium enrichment for the Department of Energy's gas centrifuge enrichment plant program.

We appreciate the opportunity to share with the committee our thoughts and concerns about nuclear power. I am going to orally present excerpts from my written statement, which we respectfully request members of the committee to read in full and which has been included in the record of this hearing.

Goodyear Aerospace has been engaged in the development and production of enrichment equipment since 1972. We feel qualified to comment on industry's perception of the Department of Energy enrichment program, and to express our opinions about the program and the need for its continuity.

We feel strongly that the United States must maintain a position of world leadership in nuclear technology and be a reliable supplier of enrichment services if we are to influence in a positive and constructive fashion the proper use of energy in the world.

This position of leadership is necessary if the United States is to exercise a positive influence for nonproliferation. We must be ready to assist nations without great energy resources. We must continue to be a reliable and cost-competitive supplier of enriched uranium to countries which want to develop a nuclear energy capability.

The on-again, off-again U.S. supply posture must end. We must continue a steady course without further delay in the GCEP construction schedule, to continue to exert leadership and be competitive in the free world markets.

We must take advantage of the centrifuge technology to stabilize prices and to retain current and future markets. You have heard or read in previous testimony by DOE officials that the U.S. share of the free world nuclear fuel market has moved from 100 percent in the mid-1970's to 35 percent in 1981.

This loss of market has injured our balance of trade and has reduced our influence in the world nuclear field. This erosion can only be stopped by continuing our efforts to remain competitive. Competitiveness in the marketplace means the ability to deliver a product at a competitive price. It also depends on the purchaser's belief that the seller is a reliable source.

It is important that we use the latest technologies at the earliest possible time to service our customers at the lowest possible price. Currently, DOE uses the gaseous diffusion process to enrich nuclear fuels. As has been stated earlier, this process is energy-intensive and, in fact, wasteful. Gas centrifuges are the only here-and-now technology that can stabilize or reduce the price of separative work sold by the Department of Energy.

Failure to take advantage of the savings possible due to centrifuge enrichment will only weaken our competitive position and result in further loss of market share; a loss that history would show is very difficult to reverse.

Only the first two process buildings of the GCEP plant are funded now. We believe careful cost analyses will show that the completion of all eight process buildings will be desirable and cost-effective. With startup costs paid, the cost of separative work units produced in the later buildings will be reduced. The attractive economics of the situation will leave no other choice than to complete all eight buildings.

Delays can only increase costs and reduce the effectiveness of DOE efforts to solicit new enrichment contracts, particularly from customers overseas.

When I testified on this topic a year ago, I said we felt the centrifuge process was proven and that the project costs were based on realistic numbers. This is certainly true today. Private industry, using facilities provided with private capital, has started the delivery of production centrifuges. Testing of the initial production units has gone well with all of the performance objectives being met or exceeded.

It is also essential that consideration be given to the reasonable return on invested private capital. Slowdowns or stretchouts of GCEP schedules will jeopardize those returns and indeed make it difficult to justify and obtain added investments required by Goodyear and others for phase II production.

The industrial production base requested by DOE has been established and the training of new employees is on schedule with excellent results. More than 200 new employees will be added at Goodyear Aerospace alone in 1982. Two thousand, three hundred persons are employed in the Portsmouth plant construction, plus the jobs created by the offsite manufacturing also in progress in 41 States.

As you know, the enrichment program is self-sustaining. Revenues now received in return for separative work sales are applied to offset expenditures, and they equal or exceed the projected fiscal year 1983 budget. This includes funds for centrifuge development and the evaluation of new enrichment technologies.

It is important that this business practice be maintained since we believe it would penalize the utility ratepayer if revenues were diverted and the SWU costs obtained, utilizing the self-sustaining budget process, were not continued.

The U.S. enrichment program has earned over $8 billion in income. Much of the revenue is from overseas customers and is a benefit to our balance of trade.

The development of advanced centrifuges has proceeded in a highly satisfactory fashion over the past year. DOE has said it can foresee a step-by-step improvement, ultimately resulting in a 100-percent improvement. We see no reason to doubt these projections since 21 percent of the projected improvement has already been achieved in machines now running in our own test facilities.

Tests are ready to begin on equipment which we feel will provide the next performance improvements. We feel strongly that uranium enrichment utilizing advanced centrifuge technology will be competitive with any other enrichment process being proposed.

While we are not able to determine exact details, new processes are being developed and existing technologies are being further developed by the DOE's competitors, France, Japan, and the German/Dutch/English consortium called URENCO. These technologies will be exploited and used unless it is clear that they will not be competitive with U.S. technology and outputs.

Advanced separation technologies are being developed and promoted within the United States. We support the development of these new technologies. If they are timely and cost effective they should be used if we are to continue to maintain our competitive posture. I would caution, however, that the new technologies must be developed in a sound and methodical manner, so that true costs can be established before we abandon more proven processes.

In your invitation to testify before this committee, you also suggested that we comment on legislative initiatives to establish a revolving fund. Without addressing any of the detailed points, I would, as a businessman, support the principle of the revolving fund legislation. The idea of supporting the current enrichment complex on a businesslike basis would be a positive step toward again establishing and preserving a U.S. position of leadership in the enrichment marketplace.

In the invitation to address this committee, one of the questions asked was relative to a budget cut and the resulting delay in completion of the full GCEP program. I would just like to address three important aspects of that question.

First is financial. We have a national commitment currently at about a $2.6 billion level for GCEP construction and its attendant equipment. Any delay will increase both the cost of construction as well as the cost of equipment. It will materially add to electric power costs because of the continued use of the high-cost SWU made by the diffusion method. Thus, the taxpayer pays twice; the delayed higher cost of GCEP, plus the higher energy utility rates.

Further, the taxpayer loses the opportunity to get the return on his investment because the Department of Energy cannot sell the high-cost SWU on a continuing long-term basis. As I said earlier, sales from enriching services pays for all of the GCEP costs.

The second area has to do with jobs. GCEP construction and equipment suppliers currently employ directly about 3,500 people. The subcontract employment in support of that base I believe is at least an equivalent number. Those some 7,000 employees or more are taxpayers, not on unemployment rolls. That payroll turns over, as I am sure you know better than I, many times as it contributes to the economy.

Any significant delay in the centrifuge production in my company would put 200 direct employees out of work and probably a like number at our subcontractors. Unemployment in our Akron, Ohio, area is at about 13 percent at this time—higher in some areas in northeastern Ohio.

I think that the industrial base consideration is also important. We represent a segment of industry that has dedicated capital, facilities, and human assets to what we perceive to be a very good, competitive opportunity. We risk these assets on a program planned to have the stability associated with a revenue-producing national asset. The instabilities associated with continuing budget cuts and program delays could prove our dedicating industrial resources to the GCEP program to be an unwise and financially unsound investment of corporate assets.

Industrial support is, I submit, a very important and positive factor in any such national undertaking. To lose the industrial support is not in my view in the national interest.

I certainly appreciate the opportunity to express my thoughts and observations and while some of my suggestions might be a bit philosophical in nature, I do believe they should receive serious consideration in establishing a sound approach to a well-organized enrichment program.

Goodyear believes DOE has made sound judgments in establishing priorities in budget presentations to Congress this year and we urge your committee to support those DOE requests.

Thank you very much.

Mr. VOLKMER. Thank you very much, Mr. Clark.

[The prepared testimony of Mr. Clark follows:]

## PREPARED STATEMENT OF ROBERT W. CLARK

Madam Chairman, I am Robert Clark, President of Goodyear Aerospace Corporation, wholly-owned subsidiary of The Goodyear Tire & Rubber Company. We are the Goodyear corporate entity engaged in the manufacture of centrifuges for uranium enrichment for the Department of Energy's Gas Centrifuge Enrichment Plant (GCEP) Program.

We appreciate the opportunity to share with the Committee our thoughts and concerns about nuclear power. I am going to orally present excerpts from my written statement, which we respectfully request members of the committee read in full, and which we request be included in the record of this hearing.

Goodyear Aerospace has been engaged in the development and production of enrichment equipment since 1972. We feel qualified to comment on industry's perception of the DOE enrichment program, and to express our opinions about the program and the need for its continuity.

When testifying before another House Committee a year ago, our concerns were very similar to today's: namely the impact of possible budget reductions on the DOE enrichment program in schedule, costs, and the U.S. position of leadership in the world marketplace.

(more)

I will, in my remarks, address these same concerns and share my opinions on the progress the program has made in the past year. I'll give you our recommendations for the future. Thanks to the combined efforts of the House Committees and Senate Committees with oversight of the enrichment budget in FY-82, enrichment programs received funding sufficient to prevent program slippage that might have occurred if larger budget cuts had been made.

The DOE enrichment situation has not changed drastically this year. The same factors still are important. The competitive position of DOE is still of concern to us. We feel strongly that the U.S. must maintain a position of world leadership in nuclear technology and be a reliable supplier of enrichment services if we are to influence, in a positive and constructive fashion, the proper use of nuclear energy in the world.

This position of leadership also is necessary if the U.S. is to exercise a positive influence for non-proliferation. We must be ready to assist nations without great energy resources. We must continue to be a reliable and cost-competitive supplier of enriched uranium to countries which want to develop a nuclear energy capability. If we can help them find low-cost energy, we reduce the risk they will develop difficult-to-monitor enrichment capabilities -- with the attendant risk of diversion of enriched materials to other-than-peaceful uses.

To project the image -- and substance -- of a reliable supplier, the on-again, off-again U.S. supply posture must end. We must continue a steady course, without further delay in the

(more)

GCEP construction schedule, to continue to exert leadership and be competitive in world markets. Continued and reliable material supplies are vital to any business venture, particularly to a capital-intensive venture such as a utility. A predictable supply of enriched material is of special concern to our overseas customers.

We must take advantage of centrifuge technology to stabilize prices and to retain current and future markets. You have heard or read in previous testimony by DOE officials that the U.S. share of the free world nuclear fuel market has moved from 100 percent in the mid '70s to 35 percent in 1981. This loss of market has injured our balance of trade and has reduced our influence in the world nuclear field. This erosion can only be stopped by continuing our efforts to remain competitive. Competitiveness in the marketplace means the ability to deliver a product at a competitive price. It also depends on the purchaser's belief that the seller is a reliable source. The U.S. is gradually losing the ability to sell at a competitive price. We must regain that ability, but it also is important that we remain a reliable and predictable supplier.

It is important that we use the latest technologies at the earliest possible time to service our customers at the lowest possible price. Currently, DOE uses gaseous diffusion to enrich nuclear fuels. This process is energy-intensive and wasteful. With the rapid rise in electric fuel costs -- at a pace faster than the general inflation rate -- the costs of producing separative work services are increasing rapidly.

(more)

The use of the gas centrifuge technology, a technology well developed and currently being readied for production in the Portsmouth gas centrifuge enrichment program, is the only here-and-now technology that can stabilize or reduce the price of separative work sold by the DOE. (DOE operating experience with the basic GCEP-type machine is summarized in Table I.)

The U.S. has made substantial progress in the establishment of gas centrifuge enrichment and has consistently improved machine performance and relaibility. Soon, we will be able to take advantage of the energy conservation the centrifuge process provides, and the cost reductions it permits in the enrichment of uranium. The failure to take advantage of the savings possible through the centrifuge enrichment process will only weaken our competitive position and result in further loss of market share -- a loss that history has shown will be difficult to reverse.

Only the first two process buildings of the GCEP plant are funded now. We believe careful cost analyses will show that the completion of all eight process buildings envisioned in the total GCEP plan will be desirable and cost-effective. With start-up costs paid, the cost of separative work units produced in the latter buildings will be reduced. The attractive economics of the situation will leave no other choice than to complete all eight buildings.

By lowering the composite selling price of U.S. separative work, the full GCEP plant production will keep the U.S. competitive in the enrichment marketplace. Delays to the projected

(more)

schedule can only increase costs and reduce the effectiveness of DOE efforts to solicit new enrichment contracts, particularly from customers overseas.

In my testimony a year ago, I said we felt the centrifuge process was proven and that the projected costs were based on realistic numbers. This is still true. Private industry, using facilities provided with private capital, has started the delivery of production centrifuges to DOE. Testing of the initial production units has gone well, with all of the performance objectives being met or exceeded.

It also is essential that consideration be given to the reasonable return on invested private capital. Slowdowns or stretch-outs of GCEP schedules will jeopardize those returns and make it difficult to justify and obtain the added investments required by Goodyear for Phase II production.

The industrial production base requested by DOE has been established, and the training of new employees is on schedule, with excellent results. More than 200 new employees will be added at Goodyear Aerospace alone in 1982. Two-thousand, three-hundred (2,300) persons are employed in the Portsmouth plant construction, plus the jobs created by the off-site manufacturing also in progress in 41 states.

This program must continue without interruption if the potential cost benefits are to be achieved. Any delay in the program will substantially increase the program's costs due to inflation. Delay also reduces the potential for further cost

(more)

savings through the ultimate retirement of gaseous diffusion plants with more efficient centrifuge enrichment plants. In fact, serious consideration should be given to the possible acceleration of the GCEP Program for additional savings.

As you know, the enrichment program is self-sustaining. Revenues now received in return for separative work sales are applied to offset expenditures, and they equal or exceed the projected FY-83 budget. This includes funds for centrifuge development and the evaluation of new enrichment technologies. It is important that this business practice be maintained since we believe it would penalize the utility rate-payer if revenues were diverted and the SWU costs obtained, utilizing the self-sustaining budgeting process, were not continued.

The U.S. enrichment program has earned over $8 billion in income. Much of the revenue is from overseas customers and is a benefit to our balance of trade. Each new reactor added to the DOE order book adds approximately $400 million to the income expected over the life of the reactor contract. Again, this is significant to our balance of trade if the reactors are overseas.

The development of advanced centrifuges has proceeded in a highly satisfactory fashion over the past year. DOE has said it can foresee a step-by-step improvement in centrifuge performance, ultimately resulting in a 100 percent output performance improvement. We see no reason today to doubt these projections, since 21 percent of the projected improvement has already been achieved in machines now running in our own test facilities. Tests are ready to begin

(more)

on equipment which we feel will provide the next performance improvements. We feel strongly that uranium enrichment utilizing advanced centrifuge technology will be competitive with any other enrichment process being proposed.

Let me also comment briefly on the competitive technologies being developed. First, while we are not able to determine exact details, it is fact that new processes are being developed and that existing technologies are being further developed by the DOE's competitors, France, Japan and in the German/Dutch/English consortium (URENCO). These technologies will be exploited and used unless it is clear that they will not be competitive with U.S. output.

Advanced separation technologies also are being developed and promoted within the U.S. We support the development of these new technologies for the reasons discussed earlier - namely, that if they are timely and cost-effective, they should be used if we are to continue to maintain our competitive posture. I would caution, however, that the new technologies being promoted should not be oversold. They must be developed in a sound and methodical manner so that true costs can be established before we abandon more proven processes.

As the President of a high-technology company, I have seen many situations over the years where new ideas were over-promoted and where decisions were made on hoped-for results rather than on proven results. The result is a familiar story -- behind-schedule positions, cost overruns, and loss of production. The enthusiasm

(more)

of the new developer must be tempered with the lessons of experience so that we proceed in a steady and predictable program. Failure to use the most advanced centrifuge technologies available today will result in the loss of market for newer technologies in future years.

In your invitation to testify before this Committee, you also suggested that we comment on legislative initiatives to establish a revolving fund for the uranium enrichment enterprise. My testimony has covered in some detail our concerns about the necessity of establishing a consistent and predictable policy for the U.S. enrichment program. I have discussed the competitive factors and have expressed concern about the need to be able to use the latest and most cost-effective technology in a flexible manner.

Without addressing any of the detailed points of pending revolving fund legislation, I would, as a businessman, support the principle of the revolving fund legislation. The idea of operating the current enrichment complex on a businesslike basis would be a positive step towards again establishing and preserving a U.S. position of leadership in the enrichment marketplace.

I appreciate the opportunity to express my thoughts and observations on DOE's enrichment program. While some of my suggestions and ideas presented today may be philosophical in nature, I believe they should receive serious consideration in establishing a sound approach to a well-organized enrichment program.

Goodyear believes DOE has made sound judgments in establishing priorities in budget presentations to Congress this year, and we urge that your Committee support the DOE's requests.

Attachment 1

THE U.S. GAS CENTRIFUGE DEVELOPMENT PROGRAM

The U.S. gas centrifuge enrichment program is the result of over 20 years of research, beginning with the initiation of experimental work at Union Carbide Corporation's Nuclear Division at Oak Ridge, Tennessee in 1960 and at AiResearch Manufacturing Company at Torrance, California in 1961. This work built upon earlier research, such as the first demonstration of an operating gas centrifuge by Dr. Jesse W. Beams of the University of Virginia in 1934.

Progress has been impressive since the first cascade of 35 centrifuges was operated successfully at Oak Ridge in 1961, demonstrating technical feasibility. A subsequent demonstration cascade, the Component Test Facility (CTF), was operated with production-scale centrifuges from both Union Carbide and AiResearch and proved the long-term reliability of large centrifuges typical of the modern generation machines. The CTF also demonstrated the ability to produce approximately 50,000 separative work units of enrichment per year with a modest number of centrifuges.

Since the initial research began, the unit capacity of individual centrifuges has increased several orders of magnitude over early centrifuges. Total operating experience has been substantial. Centrifuges of successive models have accumulated a grand total of over 2,000 machine-years using uranium hexafluoride process gas.

The baseline centrifuge is established for the Gas Centrifuge Enrichment Plant (GCEP) and is being manufactured by three commercial firms - Boeing Engineering and Construction, Goodyear Aerospace Corporation, and The Garrett Corporation. This centrifuge, designated Plc, is undergoing reliability testing in the Advanced Equipment Test Facility (AETF). Operating experience with the Plc centrifuge is already extensive. As of March 15, 1982, Plc centrifuges have operated almost a half million hours, of which 337,209 hours have been on uranium hexafluoride.

Substantial numbers of Plc centrifuges will operate in the Centrifuge Plant Demonstration Facility (CPDF), which is scheduled for startup in late 1982. The CPDF will verify the cascade operability of centrifuges produced by the three commercial suppliers. These suppliers have invested private funds totaling about $100 million in manufacturing facilities and equipment necessary to produce the baseline centrifuge.

The current production contract will provide centrifuges for the CPDF and a portion of the initial fill for GCEP. As of March 1982, hardware for 79 complete centrifuges has been received from the three manufacturers. By March 24, 1982, 21 of these centrifuges were assembled and installed in the CPDF and an additional seven were under test in the Centrifuge Verification Test Facility prior to being installed in the CPDF. The pace of installation is increasing and full operation of CPDF is expected to be on schedule.

The technology of the gas centrifuge is fully proven as the result of over 20 years of research. Performance of the centrifuge has been confirmed and its reliability has been established through detailed evaluation of current and preceeding centrifuge models. The reliability testing of the baseline centrifuge has shown excellent performance. This centrifuge is now in full-scale commercial production by three qualified manufacturers and will be ready for installation in GCEP on schedule.

Attachment 1

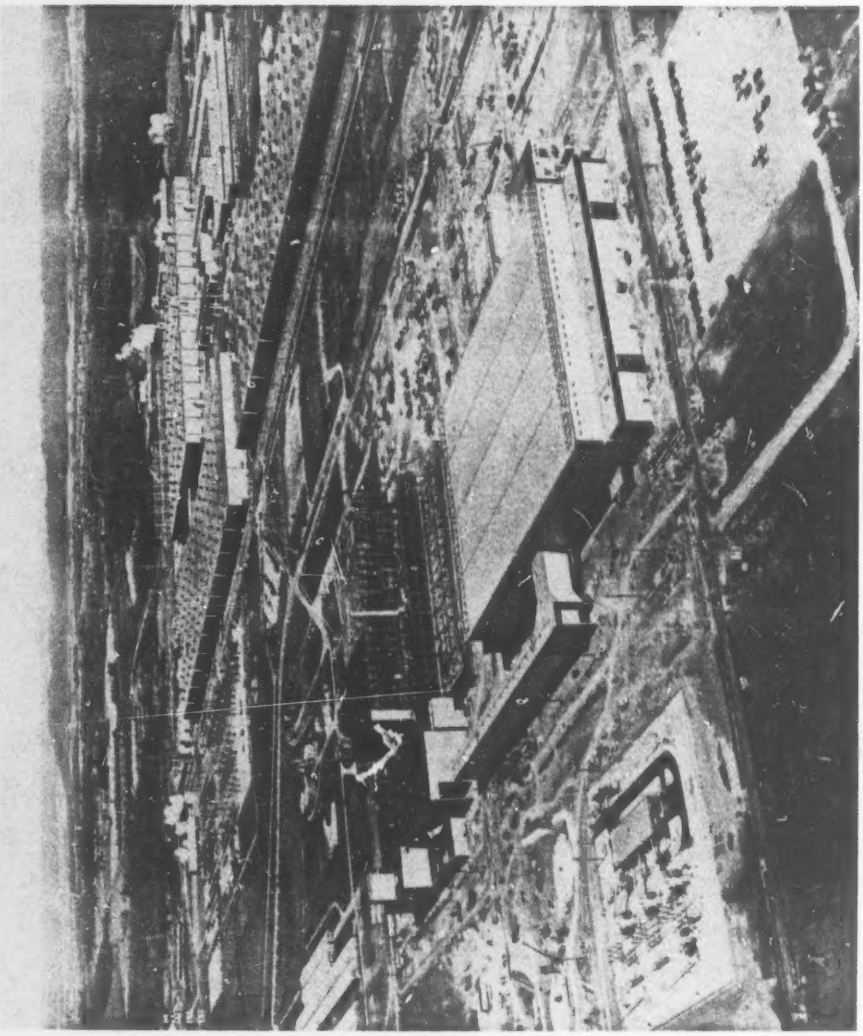
## TABLE I

## CENTRIFUGE OPERATING EXPERIENCE

| | | Machine-Years on Gas |
|---|---|---|
| 1. | Set I Reliability Testing | 496 |
| 2. | Set II Screening & Reliability Testing | 172 |
| 3. | Set II Cascade Testing * | |
| | Group 5 | 544 |
| | Group 6 | 660 |
| | Total | 1204 |
| 4. | Set III (GCEP) Screening & Reliability Testing | 83 |
| 5. | Set III Production Testing | 6 |
| 6. | Set III Cascade Testing in CPDF | ** |

* The annual capacity of this pilot plant was 50,000 separative work units.

** This facility will begin operation in October 1982.



GAS CENTRIFUGE ENRICHMENT PLANT
PORTSMOUTH, OHIO

GOODYEAR
GOODYEAR AEROSPACE CORPORATION
1210 Massillon Road, Akron, Ohio 44315
Public Relations (216) 796-3632

# ROBERT W. CLARK

## Biography

Robert W. Clark was elected president and chief executive officer of Goodyear Aerospace Corporation effective Jan. 1, 1981.

Goodyear Aerospace is a wholly-owned subsidiary of The Goodyear Tire & Rubber Company, the world's largest rubber company.

It is a major prime contractor and subcontractor in the defense and aerospace industries and also a prime contractor to the Department of Energy to produce centrifuges for uranium enrichment.

The firm has plants at Akron and Wingfoot Lake, Ohio; Berea, Ky.; Rockmart, Ga., and Litchfield Park, Ariz., and also uses Goodyear aircraft tire production facilities at Danville, Va.

Prior to becoming president, Clark was executive vice president and chief operating officer and before that, vice president of operations and director and vice president of marketing, dating from Nov. 15, 1974 when Goodyear's Aviation Products Division and Goodyear Aerospace began consolidation actions.

He also has been chairman of the Corporate Operations Committee since Jan. 4, 1979.

Clark is a mechanical engineering graduate of the University of Southern California and attended the advanced management program at Stanford University in 1972 and the Carnegie-Mellon management development program in 1980.

He is a member of the board of trustees of the National Security Industrial Association and has served on the board of directors of the General Aviation Manufacturers' Association. He also is past president of the Aviation Distributors and Manufacturers' Association, and has served as chairman of that association's market research, membership, finance and general policy committees. He also is a member of the board of directors of Summit County Junior Achievement.

Clark joined Goodyear in 1946 as a product development engineer in the Los Angeles plant, after discharge from the Navy with the rank of lieutenant. His engineering activity was in support of tire product areas and aircraft fuel tank design.

He joined the Aviation Products Division in 1950 as a field sales representative in Los Angeles and then Wichita, and managed the Dayton office before coming to Akron in 1967 to take charge of field sales and market planning. He became general sales manager of the Aviation Products Division in 1970, a position he held until the consolidation began in 1974.

Clark was born in Greeley, Colo., Jan. 7, 1925, and was raised in North Hollywood, Calif. He is active in the Episcopal Church having served as senior warden, member of choir, and chairman of the annual fund raising program and has as hobbies golf and woodworking.

He and his wife, Margaret, live at 487 Palisades Drive, Akron. They have two grown sons, Matthew and John.

1/81

Mr. VOLKMER. At this time we will hear from Mr. Sutton. Your full written testimony will be made a part of the record.

## STATEMENT OF WILLIAM H. SUTTON, MANAGER, COMMERCIAL GAS CENTRIFUGE PROGRAM, AIRESEARCH MANUFACTURING CO.; ACCOMPANIED BY W. E. SULLIVAN, MANAGER, GOVERNMENT RELATIONS OFFICE, WASHINGTON, D.C.

Mr. SUTTON. Thank you, Mr. Chairman.

My name is William Sutton. I am manager of the commercial gas centrifuge program at AiResearch Manufacturing Co., a division of the Garrett Corp., which is one of the Signal companies.

I am accompanied today by W. E. Sullivan, manager of our Washington Government relations office.

As a manufacturer of the most critical element essential to enriching uranium by the centrifuge process, we sincerely appreciate this opportunity to express our views relative to the development and use of nuclear power in general, and in particular the gas centrifuge enrichment plant currently under construction by the Department of Energy.

The Garrett Corp. by its broad diversity and the capabilities within its many product lines, is uniquely structured as an energy company. We are engaged in high technology research and development and have long been dedicated toward energy conservation as a premise of our aerospace background.

To cite a few areas in which our activities show significant contributions to conservation and, which we might add, represent a corporate investment of over $100 million in recent years. Our heat transfer capability had ready application to the recovery of waste heat in industrial manufacturing and processing plants.

Our advanced prime propulsion engines for the general aviation market have offered significant fuel economies. Our propulsion units and braking systems for high-speed rail transportation, together with flywheel energy storage systems for tracked vehicles and buses have made significant contributions to present and future economies in the surface transportation area.

Our GT-601 gas turbine engine for heavy-duty trucks offers important economies in the intercity transport of freight in the future.

The Garrett Corp.'s involvement in developing the centrifuge machine began in 1961 as a research project and our work on that program has been continuous from that date. During the course of these efforts, close to 800 centrifuges have been built by us and they have subsequently accumulated nearly 7 million hours of operation. To accomplish this, we have assigned 1,500 people to the task over the life of the program. Due to the nature of the project, it was necessary that they be of high technical proficiency and that the necessary security clearances be established.

In order to fulfill the challenge of mass producing and testing the centrifuge machines for installation in GCEP, we have leased an inactive Government facility at Sandusky, Ohio, and have expended to date some $17.5 million to make that building suitable to our specific requirements.

It is anticipated that 1,000 to 2,000 new jobs in that labor-depressed area will be created during the second phase of the GCEP production.

In addition to that investment, $15 million have been spent for capital equipment at our Torrance, Calif., plant. This is required to support and sustain the research and development phase of the program which we feel must be continued to realize the ultimate potential of the centrifuge and to dovetail with what we believe to be the real time table for the AIS process.

My purpose in mentioning the extent of our financial investment and the duration of our efforts is to establish the magnitude of my company's commitment, and the depth of our dedication to this vital program.

Nuclear power as an alternative means for generating electricity has become a significant factor in the United States. More than 12 percent of all the electricity presently consumed in this country is generated by nuclear power stations. Other countries of the world, where little or no indigenous petroleum deposits exist are dependent upon nuclear power to a much larger extent, and their commitment to this safe, efficient, and economical source of energy is on a much higher level than ours. The sources for fuel that these countries seek must meet two very basic criteria: The source must be economical and it must also be highly dependable.

At the present time, the United States is perceived by the nuclear-powered countries of the world as being an economical source but, due to vascillating nuclear policies, we are considered to be an unreliable source of enrichment and unless we pursue a course that allows us to replace the overaged, power-intensive gaseous diffusion enrichment plants with gas centrifuge enrichment plants we will soon find ourselves in the position of being uneconomical as well.

The U.S. enrichment enterprise accounted for revenues of $1.4 billion last year. Non-U.S. customers accounted for $440 million of that total.

Furthermore, the projected demand from these non-U.S. users shows a 50-percent growth of their requirements by 1995. These are significant numbers when applied to a balance-of-trade computation.

However, for reasons of reliability as mentioned earlier, the United States has seen its share of the worldwide enrichment market decline from 100 percent in 1974 to about 35 percent at the present time. For a nation with the technological stature and the desire to maintain worldwide eminence in matters as critical as nuclear power, that is a discouraging statistic.

I submit that the key to attaining both ingredients for a competitive enrichment enterprise economy and reliability, lies in the expeditious completion of the full GCEP project in Portsmouth, Ohio. This will provide clear indication to all nuclear power station operators, foreign and domestic, that the United States is intent upon becoming a dependable, enrichment supplier to the world. Any delay or reduction in magnitude of the program will only serve to further erode the confidence of present and potential buyers.

The course that this country should follow is one that provides for the maximum amount of energy-conservative enrichment services to be constructed in the shortest possible timeframe. It is imperative that the gaseous diffusion plants be retired at the earliest opportunity in order that the energy can be made available for general consumer usage and the U.S.-enrichment enterprise will benefit by utilization of a more cost-effective process.

To be more specific in this regard, I would like to point out that one scenario in the most recent enrichment operating plan of the Department of Energy clearly makes the point that, in fact, the most advantageous course to pursue from the standpoint of achieving maximum economics in enrichment is to accelerate the GCEP program.

This would result in reduced electrical costs equivalent to 4,000 MW-years, through earlier reduction in the use of the gaseous diffusion plant and, of equal importance, would result in a highly competitive average SWU price over the next 20 years.

Conversely, I would like to stress that any go-forward plan that involves the possibility of building anything less than the full 8-building GCEP complex has attendant energy and economic penalties.

Of primary concern to Garrett in the event of a drastically reduced or elongated construction schedule would be the impact on plans to invest additional capital in expanding the manufacturing facilities at Sandusky necessary to accommodate the GCEP phase II fabrication requirements.

The Garrett Corp. has invested a considerable amount of its resources, both financial and human, to the concept of providing a reliable, advanced-technology, highly producible centrifuge machine to the U.S. enrichment enterprise.

The prospect of reviewing the project's feasibility every year with the possibility of reducing the budget, and the inherent program delays that inevitably result, is one that we look upon with increasing dismay. We heartily support and endorse current legislative initiatives under consideration in Congress that would remove enrichment from the annual budget/appropriation cycle and establish a revolving fund method for insuring its continuation in an environment more conducive to its orderly, structured perpetuation.

In conclusion, I would like to say that we believe it is time for Congress to recognize that the enrichment services provided by the United States and embodied in the GCEP program are a vital entity that provide revenue to the U.S. Treasury, enhance the balance of trade, maintain visibility and insight into non-U.S. nuclear activity, furthers nonproliferation goals and achieves the objective of energy conservation. I feel that those are sufficient credentials to establish the viability of the enrichment program at Portsmouth, Ohio.

Thank you.

Mr. VOLKMER. Thank you very much, Mr. Sutton.

[The prepared testimony of Mr. Sutton follows:]

## PREPARED STATEMENT OF WILLIAM H. SUTTON

Good Morning, my name is William Sutton, manager of the Commercial Gas Centrifuge Program at AiResearch Manufacturing Company, a division of The Garrett Corporation, one of the Signal Companies. I am accompanied today by W. E. Sullivan, manager of our Washington Government Relations office.

As a manufacturer of the most critical element essential to enriching uranium by the centrifuge process, we sincerely appreciate this opportunity to express our views relative to the development and use of nuclear power in general, and in particular the Gas Centrifuge Enrichment Plant (GCEP) currently under construction by the Department of Energy.

The Garrett Corporation by its broad diversity and the capabilities within its many product lines, is uniquely structured as an energy company. We are engaged in high technology research and development and have long been dedicated toward energy conservation as a premise of our aerospace background.

To cite a few of the areas in which our activities show significant contributions to conservation and, which we might add, represent a corporate investment of over 100 million dollars in recent years: our heat transfer capability had ready application to the recovery of waste heat in industrial manufacturing and processing plants. Our advanced prime propulsion engines for the general aviation market have offered significant fuel economies. Our propulsion units and braking systems for high speed rail transportation, together with flywheel energy storage systems for tracked vehicles and buses have made significant contributions to present and future economies in the surface transportation area. Our GT-601 gas turbine engine for heavy duty trucks offers important economies in the inter-city transport of freight.

The Garrett Corporation's involvement in developing the centrifuge machine began in 1961 as a research project; and our work on the program has been continuous from that date. During the course of these efforts, close to 800 centrifuges have been built by us and they have subsequently accumulated 7 million hours of operation. To accomplish this, we have assigned 1500 people to the task over the life of the program. Due to the nature of the project it was necessary that they be of high technical proficiency and that the necessary security clearances be established.

In order to fulfill the challenge of mass producing and testing the centrifuge machines for installation in GCEP, we have leased an inactive government facility at Sandusky, Ohio and have expended 17.5 million dollars to make the building suitable to our specific requirements. It is anticipated that one to two thousand new jobs in a labor depressed area will be created during the second phase of the GCEP production. In addition to that investment, 15 million dollars have been spent for capital equipment at our Torrance, California plant. This is required to support and sustain the R&D phase of the program which we feel must be continued to realize the ultimate potential of the centrifuge and to dovetail with what we believe to be the time table for the AIS process. My purpose in mentioning the extent of our financial investment and the duration of our efforts is to establish the magnitude of my company's commitment, and the depth of our dedication to this vital program.

Nuclear power as an alternative means for generating electricity has become a significant factor in the U.S.. More than 12 percent of all the electricity presently consumed in this country is generated by nuclear power stations. Other countries of the world, where little or no indigenous petroleum deposits exist are dependent upon nuclear power to a much larger extent, and their commitment to this safe, efficient, and economical source of energy is on a much higher level than ours. The sources for fuel that these countries seek must meet two very basic criteria: the source must be economical and it must also be highly dependable.

At the present time, the U.S. is perceived by the nuclear-powered countries of the world as being an economical source but, due to vascillating nuclear policies, we are considerd to be an unreliable source of enrichment and, unless we pursue a course that allows us to replace the over-aged, power-intensive Gaseous Diffusion Enrichment Plants with Gas Centrifuge Enrichment Plants we will soon find ourselves in the position of being uneconomical as well.

The U.S. enrichment enterprise accounted for revenues of $1.4 billion last year. Non-U.S. customers accounted for 440 million dollars of that total. Furthermore, the projected demand from these non-U.S. users shows a 50% growth of their requirements by 1995. These are significant numbers when applied to a 'Balance of Trade' computation. However, for reasons of reliability as mentioned earlier, the U.S. has seen its share of the world-wide enrichment market decline from 100% in 1974 to about 35% at the present time. For a nation with the technological stature and the desire to maintain world-wide eminence in matters as critical as nuclear power, that is a discouraging statistic.

I submit that the key to attaining both ingredients for a competitive enrichment enterprise-economy and reliability, lies in the expeditious completion of the full GCEP project in Portsmouth, Ohio. This will provide clear indication to all nuclear power station operators, foreign and domestic, that the U.S. is intent upon becoming a dependable, enrichment supplier to the world. Any delay, or reduction in magnitude of the program will only serve to further erode the confidence of present and potential buyers. The course that this country should follow is one that provides for the maximum amount of energy-conservative enrichment services to be constructed in the shortest possible time frame. It is imperative that the Gaseous Diffusion plants be retired at the earliest opportunity in order that the energy can be made available for general consumer usage and the U.S. enrichment enterprise will benefit by utilization of a more cost-effective process.

To be more specific in this regard, I would like to point out that one scenario in the most recent Enrichment Operating Plan of the Department of Energy clearly makes the point that, in fact, the most advantageous course to pursue from the standpoint of achieving maximum economics in enrichment is to accelerate the GCEP program. This would result in reduced electrical costs equivalent to 4,000 MW years, through earlier reduction in the use of the Gaseous Diffusion Plant, and of equal importance, would result in a highly competitive average SWU price over the next 20 years. Conversely, I would like to stress that any go-forward plan that involves the possibility of building anything less than the full, 8-building GCEP complex has attendant energy and economic penalties. Of primary concern to Garrett in the event of a drastically reduced or elongated construction schedule would be the impact on plans to invest additional capital in expanding the manufacturing facilities at Sandusky necessary to accommodate the GCEP Phase II fabrication requirements.

The Garrett Corporation has invested a considerable amount of its resources, both financial and human, to the concept of providing a reliable, advanced-technology, highly producible centrifuge machine to the U.S. enrichment enterprise. The prospect of reviewing the project's feasibility every year with the possibility of reducing the budget, and the inherent program delays that inevitably result, is one that we look upon with increasing dismay. We heartily support and endorse current legislative initiatives under consideration in Congress that would remove enrichment from the annual budget/appropriation cycle and establish a revolving fund method for ensuring its continuation in an environment more conducive to its orderly, structured perpetuation.

In conclusion, I would like to say that we believe it is time for Congress to recognize that the enrichment services provided by the U.S., and embodied in the GCEP program, are a vital entity that provide revenue to the U.S. Treasury, enhance balance of trade, maintain visibility and insight into non-U.S. nuclear activity, furthers non-proliferation goals, and achieves the objective of energy-conservation. I feel that those are sufficient credentials to establish the viability of the enrichment program at Portsmouth, Ohio.

Biographical Information
for
William H. Sutton

Bill Sutton is Manager of the Commercial Gas Centrifuge Program for AiResearch Manufacturing Company, A Division of The Garrett Corporation.

He joined AiResearch in 1955 upon graduation from the University of Southern California, where he received his Bachelors Degree in Electrical Engineering. In 1967 he became Director of Laboratories for the company, including those involved in the early development of the gas centrifuge as it is used for uranium enrichment. In 1973 he became Chief Engineer, Ground Transportation and Industrial Power with the principal thrust being electric propulsion for rail transit. He assumed his present position in 1979 when AiResearch was awarded one of three Phase I contracts to build centrifuges for the enrichment plant being constructed at Portsmouth, Ohio.

Bill Sutton, in addition to his B.S., has completed advanced courses in electronics and control systems and has a Certificate in Business Management from the University of California at Los Angeles. He is a senior member of the Instrument Society of America and a registered Electrical Engineer, State of California.

Mr. VOLKMER. I have some questions for the panel. Mr. Grant, you stated in your testimony that value engineering programs now in process will improve the estimated life cycle costs of tens and, perhaps, hundreds of millions of dollars. Could you expand on this? For example, what are some of the value engineering programs going on in your plant, and what are the projected savings?

Mr. GRANT. I would be glad, sir, to address that subject.

Value engineering, in the sense of the centrifuge, is slightly different than in some of the military programs where the term was first evolved. In this case, we are looking at a centrifuge today that was designed and developed in at least quasi-developmental circumstances in the earlier days—earlier days in this case being 5 years ago.

In this process a design resulted that is not always the most economical to manufacture either in terms of the capital equipment required or the manufacturing processes required and those sorts of things.

The value engineering program that we have launched here is one designed to take each of the constituent components of the machine and determine, without affecting the function of the machine, how to manufacture that part as cheaply as possible.

In our particular case, we are looking diligently now at the upper suspension system in the machine. This is the part of the machine that sustains and centers the rotor in its ability to spin and be controlled. In this particular case, as I said without influencing the function being performed by the upper suspension, we have managed to, in effect, in actuality, to cause the cost of this part to be cut in half from what the original design part cost. Now, that is no reflection on the original design-work that was done but merely an indication of what can be done once you get out into a production environment and start designing parts to be built in a production capacity.

The second area that we and Westinghouse are working on independently on our own funds is the lower drive for the machine—the motive force that causes it to spin. Again, we are anticipating comparable savings to be made in that value engineering program.

Now, the life cycle cost is made up of several elements one, of course, being the initial capital cost. The second is the replacement cost—when it wears out or needs to be replaced—and with all mechanical equipment that does happen at one time or another. The third is the ease with which it can be replaced or refurbished, as the case may be. The life cycle cost improvements in this area are very significant spread over a 25-year operating life of the plant.

We, and others on this panel, are involved in looking at all parts of the machine in that context.

Mr. Volkmer. What is the estimated life of a centrifuge machine at the present time?

Mr. Grant. I believe it is a classified number. I am sorry. I wish that I could tell you.

Mr. Volkmer. I know that some of this information is classified. Personally, I do not know what is and what is not. You know better than I.

Mr. Grant. I would be happy to get that information to you by some other means.

Mr. Volkmer. Well, I can obtain that.

Would any of you others wish to comment? Mr. Sutton or Mr. Clark, do you have any value engineering programs ongoing in your facilities?

Mr. Clark. Yes, we do. The two main thrusts that we are working on are the rotors and the columns. The productivity of that value engineering approach again is classified information but the objective is to enhance the feed and withdrawal system from the centrifuge to make it more efficient. It involves new processes, new metallurgy and some new technology.

Mr. Sutton. And we are working on the lower suspension to help the machine become more stable as well as take some of the cost out of it.

Mr. Clark. Not the least of the activities of all of us, as we are tasked by the Department of Energy, is to enhance the reliability and, as Mr. Grant says, the cost effectiveness of the entire machine. That is very important to the funds spent—the reliability and cost effectiveness.

Mr. Volkmer. Mr. Grant, you commented on the set IV, set V, and set VI centrifuges for the future. What improvements are expected relative to current centrifuges for sets IV, V, and VI? Where do you see the improvements?

Mr. Grant. The set IV goal is to increase the per machine output by 50 percent. The improvements that will gain us this kind of improved output are largely speed, and in addition to that, some internal flow management of the gaseous uranium dexafluoride and thermal management. All of these, analytically, are sound technical concepts. All of them, from a hardware standpoint, are sound technical concepts and, as I mentioned earlier, none of them require any technical breakthroughs.

They are really just small logical extensions of the existing technology. As I indicated before, we make the same airplane more capable—more passengers and better performance.

The set IV program, in my view, is one that we have absolutely no problem with being able to meet. We will make a 50-percent improvement without any trouble at all. Set V and set VI, we will be up to 75 or 100 percent improvement over the existing set III or P-1C machine that we are building today.

In those two cases we have to make some material changes, but once again we are not involved with any new materials that are not currently being used in the inventory of high-technology items built in aerospace companies such as the ones represented here at this table.

Mr. VOLKMER. Mr. Grant, in your statement there is an estimate that set IV differential costs would not exceed half a billion dollars, including development costs. What are differential costs?

Mr. GRANT. What I mean by differential costs in this case are the total costs as they differ from the set III existing machine.

Mr. VOLKMER. Are these R&D costs?

Mr. GRANT. The R&D costs are included in this. Research and development costs would be actually about half of this number and the remainder would be in some of the smaller equipment changes that might be made in the plant.

As I say, these are not to exceed costs in my view. The set IV centrifuge machine, as we visualize it today, will not cost any more than the set III machine—same cost. In this sense, if there were no other changes that we had to make to the plant, then the cost of it would be exactly what it is for set III and there would only be the R&D costs involved.

As we look further into the program and if we are able to make further improvements, it is possible that we might have to change some small equipment items in the plant. Therefore, I have thrown in a contingency of roughly another $250 million to account for what might pop up in this regard. However, the research and development I estimate at not more than $250 million and the balance of plant changes a similar number.

Mr. VOLKMER. What about the differential costs between set IV and set V?

Mr. GRANT. That, of course, as I said before is like any technology at this stage, far less certain. I think that R&D costs on set V and VI combined might run $500 million over the time period we are talking about.

Schedulewise I would guess—or my estimate today—is that there is little impediment to it being on line in some production capacity for set V and, possibly, set VI—or maybe we would leapfrog set V and go directly to set VI—by 1995.

Mr. VOLKMER. Anybody have anything that they wish to add to that? Mr. Clark? Mr. Sutton?

Do you, generally, agree with that?

Mr. CLARK. Yes, I agree with that.

Mr. SUTTON. Yes.

Mr. VOLKMER. OK.

Mr. Clark, in your testimony you state that it is essential that consideration be given to the reasonable return on invested private capital. Slowdowns or stretchouts of GCEP schedules will jeopardize those returns and make it difficult to justify and obtain the added investments required by Goodyear for phase II production.

Could you give us an approximation of what Goodyear's investment to date has been?

Mr. CLARK. Certainly, to date our investment, since its inception, has been $52 million.

Mr. VOLKMER. All right. What added investments are required for phase II production?

Mr. CLARK. Our current outlook to generate the total facilities and capability for phase II would mean another $34 million of capital investment.

Mr. VOLKMER. What level of return on this investment do you expect on the total venture given the current schedule?

Mr. CLARK. Given the current schedule, our total outlook is that we would expect a return on investment in the neighborhood of about 18 percent.

Mr. VOLKMER. If the schedule, let us say, had an additional 1- or 2-year slippage, what impact would that have on your expected returns?

Mr. CLARK. Our expected return would be reduced to about 12 to 14 percent with a 2-year slippage.

Mr. VOLKMER. Might there be an additional investment required for a 1-year or 2-year slippage?

Mr. CLARK. That $34 million of investment is based on the current schedule. We would defer the capital investment as a function of slippage and the capital cost would be higher. I do not have the magnitude.

Mr. VOLKMER. Mr. Clark, I believe you testified that, if anything, we should accelerate the GCEP program for additional savings. How much earlier than 1994 could GCEP be completed?

Mr. CLARK. DOE's calculations indicate that 2 years is a practical timeframe to consider a cost-effective enhancement of the program or getting it in position sooner. I am sorry but I cannot predict what the savings might be.

Dick, do you have that figure. I just do not remember, to be quite frank about it.

Mr. VOLKMER. Well, let me estimate that there will be additional dollar savings in electrical energy.

Mr. GRANT. Oh, yes. That is enormous of course. Let me point out another interesting aspect of what happens when schedule slippages occur.

When you start to look at how you—and this gets back to the time value of money—amortize the total cost over the period of performance, calculate interest on the money, compound it, and then pay it back—just like you do your house loan for example—the slide from 1993 to 1994 increased the amortization costs—you are looking out in the future now—by almost $5 billion, $4.8 billion to be precise. That 1-year slide costs you—just if you were treating those capital dollars as dollars that had to be amortized the same way that your house payment is.

Could I comment briefly on the acceleration of GCEP?

Mr. VOLKMER. Yes.

Mr. GRANT. The thing that is impacted most seriously, again in terms of looking at the day-by-day numbers associated with slide, and again calculating the amortized costs which you would have to add to the price of a SWU, slides cause the point at which you cross over diffusion, when you add returning investment to the taxpayers, to slide out.

My personal view and one that has been augmented somewhat by some of the work we have done with some of the A&E firms and so forth, looking at possible additional facilities in other countries and those sorts of things, indicates to me that it would be possible to put GCEP on line in 1991 at the 8.8 million SWU capacity. If it were on line in 1991 its cost including—again, amortizing the value of the total investment over time like you would your house payment—would be less than a diffusion SWU on the day it came on line.

Mr. VOLKMER. OK.

Mr. Clark, and anyone else who wants to comment on it, you caution with regard to the new technologies that they should not be oversold. I think, Mr. Grant, that you commented briefly in support of the advanced isotope separation program. My question is, as one who is fairly new to the total program, could this caution apply also to the advanced centrifuge technology?

Mr. CLARK. My answer to that is "No." Mr. Grant gave you a detailed explanation of the status of where we are in the development of the advanced centrifuge so my answer is "No."

The next question relative to "are we convinced" of the technology, in my testimony I indicated that right now, on tests, they are machines with a 21-percent improvement and that is a product of technological enhancements that have been developed in a research and development sense over the period of the last 18 months to 2 years.

I share Mr. Grant's view that we are not trying to change the laws of physics. We are not inventing new materials. We are advancing technology in a very logical and progressive manner. Our view is that the objectives of the advanced centrifuge technology are well within hand and it is a matter of proving that and reducing it to operating processes and state of the art. It is not out of character.

Mr. VOLKMER. Do we have any of the centrifuge machines—is that appropriate to call them machines?

Mr. SUTTON. That is appropriate.

Mr. CLARK. Yes.

Mr. VOLKMER. Do we have any on line at the demonstration plant at the present time?

Mr. GRANT. The centrifuge plant demonstration facility in Oak Ridge, Tenn., has some 25 percent of the machines installed in place, I believe right now.

The characteristic of the process is that until you have a certain number of machines installed, you do not start up the process. Those machines are sitting there waiting right now for installation of the remainder of them and then they will start.

Mr. VOLKMER. How many machines will have to be in place before you can run the demonstration facility?

Mr. GRANT. I confess I do not remember what the minimum number is that we can run in CPDF.

Mr. CLARK. I believe it is less than 100 percent. They will have a cascade available for trial.

Mr. GRANT. That is right.

Mr. VOLKMER. At about what time?

Mr. CLARK. About October of this year.

Mr. VOLKMER. All right.

When they begin operating, will they actually perform the enrichment process?

Mr. CLARK. Yes.

Mr. VOLKMER. This has to be proven out?

Mr. GRANT. That is true. I mentioned earlier in my testimony that 100 metric tons of enriched uranium have been produced by the centrifuge and that has been done at K-25 in Oak Ridge in facilities similar in nature to the CPDF that we are operating in now but not as complete a replication of the actual production process.

Mr. VOLKMER. Mr. Sutton, you state that of primary concern to Garrett in the event of a drastically reduced or elongated construction schedule will be the impact on plans to invest additional capital in expanding the manufacturing facilities at Sandusky necessary to accommodate phase II fabrication requirements.

What do you consider a drastically reduced or elongated construction schedule?

Mr. SUTTON. Any delay——

Mr. VOLKMER. One year? Two years?

Mr. SUTTON. One year, two years, the effect it has is pushing out the breakeven point on a straight business basis. There is going to be a limit on what I am sure I can convince our directors to invest their money when they are not going to get a payback for many years. So, I would think that a 1-year or 2-year slip would put the program in jeopardy at our place.

Mr. VOLKMER. What do you mean by "put the program in jeopardy"?

Mr. SUTTON. We still have an option of whether or not to bid phase II.

Mr. VOLKMER. Fine.

Mr. SUTTON. We are looking at our estimates of——

Mr. VOLKMER. With the total amount that you have testified that you have invested in it, you would be looking at the possibility of dropping out altogether?

Mr. SUTTON. If, because as you go into phase II, our estimate of the investment required to meet the production schedules is like $100 million more.

Mr. VOLKMER. In other words, you are looking at $100 million additional investment on top of what you already have?

Mr. SUTTON. That is correct.

Mr. VOLKMER. I suppose that you can each answer this. What were the reasons, behind your individual firm's decision to participate in the gas centrifuge enrichment program?

Mr. SUTTON. If I can answer first, we have been in it the longest?

It happened 21 years ago and I guess that I was with the company at the time. Our company manufactures and specializes in high-speed rotating machinery and it was a natural thing to get into. Quite frankly, the company does not normally get into development cycles that take 21 years to turn it into production, but nevertheless that was our driving force and we are still dedicated to it.

Mr. **Volkmer**. Mr. Grant?

Mr. **Grant**. I suppose our reason is a little bit different in some respects.

The technology is very compatible with aerospace kinds of technology which, of course, was part of the reason we thought it was something we could do. The Boeing Co. started out in 1972 to make sure that our primary product would still be flying 30 years from now.

Eighty percent of the $10 billion sales of the Boeing Co. come from airplanes. As I say, we would like to be flying those airplanes in the future. One way to do that is to get into the mechanism for preserving the kinds of fuels that our airplanes can burn. We have been involved in every alternate energy form in one way or another since 1972 in the quest to prevent, where possible, the use of what can be potentially transportation fuels in stationary applications.

When you couple this with the tremendous attractiveness of GCEP as a conservation measure and the idea that it was a program that we could enter without losing money—also this is an unpopular thing to do in our company—it had a natural attraction for all those reasons of our interest in preserving the liquid hydrocarbon fuel base of this Nation.

Mr. **Volkmer**. Mr. Clark?

Mr. **Clark**. The Goodyear Tire Co., in the form of the Goodyear Atomic Corp. which is another subsidiary, has been the operating entity for the Portsmouth Gaseous Diffusion Plant since its inception. That puts us into the enrichment picture in about 1952.

As any company would look at this kind of an opportunity, we evaluated the demand as being very real. We think that nuclear power is mandatory as we look out into the future and it was an opportunity for diversification, to continue our interests in nuclear power as developed by our operation in the Goodyear Atomic Corp. We looked at it as a very real and honest opportunity for our diversification and a place to invest our capital.

Mr. **Volkmer**. I would like to ask all of you if your firms have any intention of participating in a proposed joint venture with Australia to build a uranium enrichment plant in that country.

Mr. **Clark**. I will speak to that.

Our firm is one of the firms that has made a proposal to Australia. Our fundamental belief is the fact that the Australians will make a dedication to a private venture which will provide them with a vertical integration capability as a country, since they have the richest supply of uranium that is available, it is natural that they would want to exploit their resources.

Since we believe they are going to do it anyway and since the Government, in essence, has agreed that they will approve the use of our technology in that venture, then it is logical for us to consider participating and we have just started. The technology selection decision has not been made by the Australians and probably will not be made until June or July. We believe that it is viable for the

Australians to consider an enrichment venture, and we will participate with them if the opportunity presents itself.

Mr. GRANT. My position on that is a little different than the other two gentlemen at the table.

I spent about $100,000 coming to the conclusion that I would not want to propose to the Australian venture. My primary reason for that was that I simply must retain my resources for the U.S. program which has to come first for us.

Mr. VOLKMER. Mr. Sutton.

Mr. SUTTON. We did propose for the Australian venture pretty much the same conclusions reached by Mr. Clark. Our company did, before the Nuclear Fuel Assurance Act did not pass, look at private enrichment. Our parent company, the Signal Co., has quite a background in plant design. We just felt it was logical and really all we are proposing to do is to join their industrial team for a 2-year feasibility study to decide whether it even makes sense for them.

Mr. VOLKMER. Mr. Sutton and Mr. Clark, I would like to ask you if either of your firms has obtained any assistance or any type of commitments from this or any previous administration to support your efforts to obtain this contract with Australia?

Mr. CLARK. Well, support must come in a legalistic way in terms of authorizing the use of U.S. technology and in protecting the technology at a national level. It is the responsibility of the Government to take that action through the Congress as well as through the auspices of the Department of Energy.

I have Mr. Feldscher, the business director for the centrifuge division with us who has participated. John, would you like to add anything to that?

Mr. FELDSCHER. Just that at this point in time there have been no firm commitments to permit the transfer of technology. There was a clear understanding that before any firm agreements can be made they have to come before Congress. We understand that——

Mr. VOLKMER. For the transfer of technology?

Mr. FELDSCHER. That is right.

Mr. VOLKMER. In other words, without that consent there would be a legal question as to whether or not you could participate. Is that correct?

Mr. FELDSCHER. That is clearly understood by all parties.

Mr. SUTTON. Absolutely.

Mr. FELDSCHER. On the basis that their technology selection decision has not been made, the request for legislative approval has not been passed to Congress. To do so at this time could be a time wasting effort. If they do select U.S. technology, then a request for approval will be to Congress. That is our understanding.

Mr. CLARK. As a matter of interest, Mr. Chairman, the status now is communication in an unclassified manner. That is the limit to which we are able to pass our proposals to the Australians for preliminary reviews of the value of the technology in the competitive sense.

Mr. VOLKMER. Who else is competing to your knowledge?

Mr. CLARK. All of the available foreign competition precisely the Japanese, the French and their process and the URENCO group in Europe are all competing for the opportunity.

**Mr. Volkmer.** Do any of you wish to comment or expand on some of the reasons for the reduced amount of world-wide uranium enrichment services that we have supplied in recent years?

**Mr. Clark.** I am not sure I understand the question.

**Mr. Grant.** Are you talking about operating the existing plants at 40 percent?

**Mr. Volkmer.** No, I am talking about the total amount. In other words, at one time we did 100 percent of the world's enrichment.

**Mr. Grant.** Oh, the loss of market.

**Mr. Volkmer.** We have lost some of the market. Is that solely because of the dollar figure, the cost figure, the reliability, or what? Is it a combination of factors or what is it?

**Mr. Grant.** It is very hard to separate those two factors. There are some nationalistic issues involved of course, in the case of the French with their diffusion plants, and to a lesser extent the European consortium. Certainly the Japanese have a national interest involved there.

I think that it is fair to say that it is a very difficult job for someone to be out there marketing a product in the international market as we experience with airplanes every day. Someone else is offering a lower price on the one hand, and someone else is offering it where it can be assured to be exported in a timely way.

It is fair to say that the international community is—perhaps I could generously describe it—is somewhat skeptical about our export policies where nuclear things are concerned.

**Mr. Volkmer.** In other words, they could not be sure whether or not they could get the product when they needed it?

**Mr. Grant.** Sure. These people are contracting for years and years of operation of a very capital-intensive facility—a nuclear power plant—and they absolutely must be assured of a supply of fuel being available.

**Mr. Volkmer.** Do you other two agree on that?

**Mr. Clark.** That is a very good answer. That is correct.

**Mr. Sutton.** Correct.

**Mr. Volkmer.** Do any of you three believe that we could ever get to the point of having private enterprise operating our uranium enrichment facilities?

**Mr. Clark.** I cannot speak for having been involved in the activities that went on in 1975. My current view is that this has been debated in Congress at length. The program has proceeded and the invested capital has been put in place at a national level, especially the GCEP plant. I think it would be an insurmountable task to translate that then back to the private sector in terms of the ability to absorb the inter-related problem—to absorb that capital—as an investment. The inter-related problems of marketing under the controls of a monopsony which the Government represents, who puts constraints on it and then provides an opportunity for private invested capital to market it, I think it would be nearly an impossible task.

I believe that the direction that is being taken now, is in fact, the proper direction in terms of controls and management.

**Mr. Volkmer.** In other words, are you saying, Mr. Clark, that if for some reason or another GCEP was terminated—which we do not want to happen, but let us assume that happens then—in your opinion there is no possibility that private enterprise would pick it up and go with it even though we know that tremendous savings would be achieved if we used centrifuges instead of gaseous diffusion technology?

Mr. GRANT. I do not think that is what Bob meant——

Mr. VOLKMER. I know that, but suppose we assume that the GCEP was terminated?

Mr. GRANT. Terminating the GCEP at this point, if there were some vehicle that terminated GCEP on day one and it became a private venture on day two, I think that is a very different circumstance and one that is doable but doable over a very long time frame.

Let me take you back a minute. I was involved in the privatization enterprise that actually started in 1973 and progressed on through the failure of the Nuclear Fuel Assurance Act. I was the Boeing representative to two—actually I would say three—private ventures, potential private ventures, in that enterprise.

The hurdles to it are tremendous. There are institutional barriers that are tough to overcome. There is no way that the private sector, for example, can get into this business without having some international involvement in it as one example. There are the questions that Mr. Clark raised—the Government's monopoly and how it is going to behave, vis a vis private enterprise that is operating either in competition with or in concert with the Federal Government.

The time period is what concerns me. What happens is that all the schedule delay cost problems that I have alluded to earlier in this testimony would occur if, for example, someone decided to terminate GCEP without having all this preliminary work done so that on day two, in fact the private sector could move in and complete the plant and proceed smartly to produce a product.

I think that as a practical matter that gestation period is very long. I think that the Nuclear Fuel Assurance Act passage you must remember, was only the first step in getting to privatization and that was a 2½-year process, just getting to the first step.

There are at least three or four distinct legislative actions that would probably have to occur and probably have to occur in a series. I do not see that happening in under 3 years by itself.

The infrastructure problems are terrible things to cope with. We are starting from zero as we are today.

That brings me then to the statements that I made about the revolving fund. One of the reasons why I am so excited about this as a prospect is that I think it lays the groundwork for ultimate transfer to the private sector. It gets over many of the institutional barriers and infrastructure problems and legislative hurdles that I have just mentioned. It provides then a period during which the enterprise can, in fact, be measured for its efficacy as a businesslike approach.

Let me make a proposal that has been playing around the corners of my mind for some time on the revolving fund. The revolving fund has been talked about largely in the form of bills that have been prepared—and very good bills—to support the idea. However, the tough part of the revolving fund is putting together the business structure that does business as it is wrapped around a uranium enrichment enterprise.

I wonder if it would not be appropriate for the Congress, perhaps this committee, to ask for and form a task force of business people around this country—to put together a set of business leaders to do this front-end work on a "what if" basis, to put together the financial schemes, the ways of conducting business, the contracting practices, the operating practices and procedures, the strategy and planning aspects of what would have to go into this enterprise. Until you get this on the table, it is going to be very difficult to talk intelligently about what that next step really is.

This is only a suggestion that you might consider for the future.

Mr. VOLKMER. Would you envision that along with having a revolving fund you would also have a quasigovernmental corporation operate the uranium enrichment enterprise?

Mr. GRANT. No; it does not have to have that kind of status, at least as I see it right now. It could be that there is some point that I have missed that would require it ultimately. However, it still has to be structured very much like that sort of thing. The structure has to be there to operate it. It still has to contract, it still has to do business, it still has to market the plan.

Mr. VOLKMER. You are saying that the business parts of it still have to be there?

Mr. GRANT. Yes, sir.

Mr. VOLKMER. Whether it is operated by DOE or whoever?

Mr. GRANT. Yes, sir.

Mr. VOLKMER. Mr. Sutton?

Mr. SUTTON. I pretty much agree with what the gentlemen have said.

I think the revolving fund is probably the logical first step and I think that Mr. Grant's proposal is an interesting one.

I would further only comment that possibly the point of privatization would be better placed with the AIS concept because it is a much lower capital-intensive technology and it would provide the time frame to logically transition.

Mr. VOLKMER.

That concludes my questions. I wish to thank the panel very much for good cooperation and taking the time to be here. The information that you provided us with was interesting.

At this time I would like to have our next witness Dr. J. Robert Merriman, director, enrichment and technology, Union Carbide Corp., Nuclear Division.

Mr. Merriman, I would appreciate it if you would identify the two gentlemen who are there at the table with you for the record?

## STATEMENT OF DR. J. ROBERT MERRIMAN, DIRECTOR, ENRICHMENT TECHNOLOGY, UNION CARBIDE CORP., NUCLEAR DIVISION, ACCOMPANIED BY RICHARD L. HOGLUND, DEPUTY PROGRAM MANAGER, ADVANCED ISOTOPE SEPARATION PROGRAM, AND WILLIAM B. ARTHUR, ENGINEER, ADVANCED GAS CENTRIFUGE PROGRAM

Dr. MERRIMAN. Thank you, Mr. Chairman.

I am pleased to have with me today two members of our enrichment team. On my left is Bill Arthur and on my right is Dick Hoglund.

Mr. Chairman, we certainly do appreciate this opportunity to discuss the new U.S. processes for uranium enrichment.

Mr. VOLKMER. Dr. Merriman, you may summarize your testimony if you wish and a copy of your written statement will be made a part of the record.

Since we did provide, as you indicated, a copy of our complete statement, I will make a brief summary at this time.

Paul Vanstrum and I discussed the new enrichment technologies in testimony before this committee on September 22, 1979. Since that time, the overall picture in uranium enrichment has changed in a number of significant respects. First, with respect to our gaseous diffusion plants, the capacity expansion programs—CIP and CUP—have been essentially completed now. These were very successful programs, I might add.

Next, as you well know, construction of the gas centrifuge enrichment plant—GCEP—located at Portsmouth, Ohio, is well underway.

In addition, the centrifuge manufacturers from whom you just heard are building production facilities that will soon be ready to mass produce centrifuges.

The AIS program has made excellent progress and has reached the point where selection of a single process is warranted and where engineering development and demonstration can begin for the selected process.

The advanced gas centrifuge program—our AGC program—which was started in 1980, is also making good progress toward its initial target and offers significant additional potential.

On the negative side, as you are aware, the market for enrichment services continues to decline. In view of the reduced market and our large stockpile of enriched uranium, the U.S. gaseous diffusion plants are currently operating at approximately one-third of their capacity.

On the foreign scene, construction of the Eurodif gaseous diffusion plant, which has a separative capacity of nearly 11 million SWU per year, is now complete. In addition, the URENCO multinational gas centrifuge projects are continuing. The Japanese, our largest non-U.S. customer, are very active in research, development, and demonstration of gas centrifuge and ion exchange technologies. As you pointed out, the Australians are holding discussions with a number of nations, including the United States, concerning selection of a partner for their planned enrichment program, and a joint German-Brazilian demonstration plant using the nozzle process is under construction in Brazil.

As you can see, the uranium enrichment picture is quite different than it was in the fall of 1979.

With this background, I would like to offer some brief comments on the gas centrifuge and AIS programs.

The Nuclear Division of Union Carbide has been a key contractor in the gas centrifuge program since its inception in the early 1960's. As is true for all our enrichment programs, our gas centrifuge work is conducted under contract to the Department of

Energy. Currently, our centrifuge activities involve either a lead or a major support role in almost every aspect of the GCEP project and the advanced gas centrifuge development program.

From this point of view, I would like to note that, as regard GCEP, its ability to enhance the U.S. enrichment business with an economically attractive, energy efficient process cannot be underemphasized and should not be obscured.

Long-term uncertainties in the gaseous diffusion plant energy availability and cost picture continue to be of concern. Also, as I have just indicated, competition from foreign suppliers has become more significant, emphasizing the importance of maintaining a technical lead.

The reduced demand for enrichment services has diminished the need for total separative capacity, but we believe it is appropriate to look at using GCEP capacity to replace gaseous diffusion capacity if the demand for enrichment services does not rebound in the 1990's.

In this context, it appears to us that GCEP forward cost figured from the end of 1982 is indeed likely to be lower than the out-of-pocket cost from existing diffusion plants in the 1990's if advanced centrifuges are deployed.

There is a significant potential for improvement in the gas centrifuge performance beyond that which is now planned for introduction in GCEP. Our scientists and engineers have looked at a number of advanced machine candidates and have postulated that, for machines that are generally compatible with the overall GCEP plant design, a factor even as high as four improvement over the first machine introduced at GCEP may ultimately be possible.

Looking realistically at the near term, we think a factor of two improvement is demonstrable within the next decade, provided we have an aggressive, advanced gas centrifuge program.

We project that, as the AGC program continues to develop improved machines, these can periodically be incorporated into GCEP as it is cost effective to do so. Under some scenarios, the incremental costs projected for these improvement programs are competitive with costs projected for AIS.

While I recognize that reducing the energy requirements for our enrichment complex and maintaining adequate flexibility to respond to what we hope will be an eventual upturn in the SWU market are very important, I wish to emphasize that the key factor making GCEP economically attractive is the opportunity to incorporate advanced centrifuges.

I would like to conclude my comments on the gas centrifuge by summarizing the status of the AGC program. As you have heard, we are making good progress on the set IV program, which has an initial target of 1.5 times the capacity of the first GCEP machines—in other words, a 50-percent improvement.

In laboratory demonstrations on full-size centrifuges, we have already achieved about half of the initial performance target. We believe this machine can be ready in a timeframe which will give DOE the option of implementing its current plan to introduce it beginning with process building No. 3 and to retrofit buildings 1 and 2.

Turning now to the AIS program, let me note that considerable progress has been made in the last 2 years in the scientific and early engineering exploration of the three competing processes.

We have been involved in the AIS program for 10 years—again, since the program's inception. Our principal activities include technology development support; engineering; process evaluation; and, of greater future emphasis, engineering development and demonstration.

In our R&D efforts we have been assigned some key responsibilities from each of the labs and have worked with each of the process proponents to support their programs and to help put each process in the best possible competitive position.

In addition, our direct involvement in the R&D effort has provided us with a firsthand insider's view of the process technology, which has been very beneficial in our evaluation work.

Over the last 18 months, substantial engineering design activities have also begun for the AIS processes. During this period we completed two major tasks working with each of the laboratories: Conceptual designs of the AIS development module and preconceptual studies of production plants.

The purpose of the development module conceptual designs was to establish an accountable project scope, cost estimate, and schedule for the line item construction project for this important facility. We continue to believe that, after process selection, the development module will be the most important next step in the AIS program.

The development module will provide the basis for evaluating the readiness of AIS for production use. The hard data acquired from the development module construction and operation are necessary, in our view, to establish the engineering and economic information with which we can realistically and confidently make decisions regarding deployment of AIS in the U.S. enrichment enterprise.

In the area of process evaluations, I would like to point out that for 40 years we have conducted technical and economic evaluation of many uranium enrichment processes for DOE and its predecessors.

Since our work is in support of the U.S. Government, our only objective is to provide information which will help identify the best technology choices for the Government program.

As a part of this effort, for the last several years, since 1975 in fact, we have performed evaluations of AIS technology status and economic potential. This has certainly been one of our most challenging, exciting, and important evaluation programs.

During this period, as more has become known about the AIS processes, we have also continued improving our evaluation techniques. We believe we have developed and applied methods in this work which provide credible projections of process economic potential, recognizing the many uncertainties which certainly do exist at this stage of the program.

Having good analysis methods, of course, is not good enough. You also need good input information if the analysis is to be worthwhile. To obtain input information, we draw on our own AIS program staff; we draw on other experts from other programs in the nuclear division; we draw on experts and consultants from many other companies; and, most importantly, we draw and rely very heavily on an outstanding and exemplary AIS peer review effort, which has been underway for some time now.

As you know, the AIS process selection decision is scheduled to be made in April 1982. To help establish the technical basis for its decision, DOE established a Process Evaluation Board. The Board has been active for several months now, reviewing the various programs and the technical and engineering data.

We have worked hard to support the Board's activities in the areas assigned to us. We believe that the key factors in selecting an AIS process are: The adequacy of the scientific and technical data base, the readiness for engineering development, the economic potential, the intrinsic process flexibility and potential for improvement, and the demonstration and deployment plans and their cost.

Having carefully thought about these points ourselves, we agree with DOE that a process selection should be made now. We believe the benefits will be much greater if we move forward expeditiously with a single process that is ready to take the next step. This will accelerate the engineering demonstration of an AIS process at a funding level consistent with current projections of the DOE budget.

We believe an AIS selection can be made with acceptable risk and that this action is consistent with the national objective of having the United States continue as the world leader in enrichment technology.

In summary, there are many uncertainties that must be taken into account in planning for the future of the enrichment step of the fuel cycle. These uncertainties are both short range and long range and involve both domestic and foreign markets.

It is our view, therefore, that those steps should be taken which best preserve our options to continue as the world's leading low-cost supplier of reliable enrichment services. Such an approach, we believe, also best serves the U.S. nonproliferation goals.

Based on our view of the enrichment situation, we offer the following conclusions and recommendations:

We should continue to go forward with the construction of GCEP with the objective of having the first two buildings on line in the 1980's.

We should maintain viable plans and preserve the option to have the six additional buildings on line by the mid-1990's.

We should continue to push hard on the development of the set IV improved GCEP machine with the objective of having it qualified and ready for installation in process building number three, as well as having it ready for retrofitting in buildings one and two.

The set IV advanced gas centrifuge program continues to look very attractive, both from the standpoint of its high benefit-to-cost ratio and from its strategic value in providing an important alternative to gaseous diffusion capacity if electric energy costs rise or if there are power availability problems for the gaseous diffusion plants.

At the same time, funding support should be provided to capitalize on the good potential for even more advanced centrifuge technology, with a goal of making much better units available for production use in the 1990's.

Our current view of the economic potential of these machines suggests that, with a strong but reasonable development effort, they could be competitive with an AIS process in the same timeframe.

The country's enrichment program in the 1990's will benefit by pursuing advanced gas centrifuge and AIS technologies competitively to the point of comparative evaluation in the late 1980's.

Accordingly, we urge that the AIS process selection decision be made on the present schedule. We feel that sufficient information for choice has been made available to the Process Evaluation Board, and we endorse and support the selection approach being followed by DOE.

The selection is needed now in order to apply development resources to the best advantage. In that regard, we strongly recommend proceeding with the development module and the supporting engineering development program for the selected AIS process. This is the reasonable next step which must be taken in order to provide the information needed to determine what role AIS can play in the future enrichment enterprise in the United States.

AIS has the potential for providing the United States with the world's best lowest cost enrichment technology; but if this step is not taken in a timely manner, AIS cannot be ready on a schedule which will allow it to compete with AGC for deployment in the 1990's.

We again endorse and urge that innovative marketing of U.S. enrichment services be pursued in the foreign market. It is the best way to build credibility as a supplier and to reduce motivation for proliferation by other nations. In addition, it will be of substantial economic benefit to the United States.

Studies of enrichment enterprise strategies should be updated continually to reflect accurately the current projections of market technology and economics. We certainly believe decisions in uranium enrichment should continue to be made, using sound, hardnosed business analyses.

Only through such studies of alternative enrichment business scenarios can data be provided for management decisions which use the many available options to the best advantage. Current studies continue to show that the benefits of deploying advanced enrichment technologies in the 1990's are substantial and amply justify the recommended research, development and demonstration investments.

Mr. Chairman, that concludes my summary. I would be pleased to address any questions that you might have.

[The prepared statement of Dr. Merriman follows:]

## PREPARED STATEMENT OF PAUL R. VANSTRUM

### INTRODUCTION

Chairman Bouquard and members of the Committee, we are pleased to have this opportunity to discuss the new U.S. processes for uranium enrichment, namely, the gas centrifuge and Advanced Isotope Separation (AIS) processes, and to respond to the questions about Union Carbide's role in these activities which you raised in your letter requesting our testimony. We discussed these subjects in testimony before this Committee on September 22, 1979. Since that time, the overall picture in uranium enrichment has changed in a number of significant respects--completion of some milestone events, progress in technology development, changes in the market outlook, and changes in some important economic factors. We would like to preface our comments today by briefly reviewing some of these changes.

- Completion of CIP/CUP. With respect to our gaseous diffusion plants, the capacity expansion projects (CIP and CUP) are now essentially complete, increasing the diffusion plant capacity by 10 million SWU/yr (to 27 million SWU/yr) at a cost of $1.5 billion.

- Initiation of GCEP. Construction of the Gas Centrifuge Enrichment Plant (GCEP), located at Portsmouth, Ohio, is well under way (Chart 1). In addition, centrifuge manufacturers are building production facilities that will soon be ready to mass produce centrifuges for the first two GCEP process buildings.

- AIS Process. As we will discuss in more detail, the AIS program has made good progress and has reached the point where selection of a single process is warranted and where engineering development and demonstration can begin for the selected process.

- AGC Program Start. As we will also discuss, the Advanced Gas Centrifuge (AGC) program, which was started in 1980, is making good progress toward its initial target and offers significant additional potential. Progress to date has substantiated the value of several new concepts proposed for the first scheduled AGC design.

- Reduced Demand for U.S. Enrichment Services. On the negative side, as you are aware, the market for enrichment services continues to decline because of cancellations and deferrals of planned reactors.

- Curtailed Operation of GDPs. In view of the reduced market and our large stockpile of enriched uranium, the U.S. gaseous diffusion plants are currently operating at approximately one-third of their capacity.

- Increased Foreign Enrichment Capacity. Construction of the Eurodif gaseous diffusion plant, which has a separative capacity of nearly 11 million SWU/yr, is now complete. In addition, the Urenco multinational gas centrifuge projects are continuing; the Japanese (our largest non-U.S. customer) are very active in research, development, and demonstration of gas centrifuge and ion exchange technologies; the Australians are holding discussions with a number of nations, including the U.S., concerning selection of a partner for their planned enrichment program; and a joint German-Brazilian demonstration plant using the nozzle process is under construction in Brazil. Many of these ventures involve participants whose utilities presently hold U.S. enrichment services contracts.

- GDP Electric Energy Cost. A key parameter affecting the future economic attractiveness of existing gaseous diffusion plants versus our newer technologies is the differential rate of escalation of electricity costs relative to the general inflation rate. Recent estimates of this differential escalation rate have been significantly lower than values used in the past; consequently, diffusion plant separative work costs are expected to change more slowly than had been projected in earlier studies.

As you can see, the uranium enrichment picture is quite different than it was in the fall of 1979. With this background, we would like to offer the following comments on the gas centrifuge and AIS programs, emphasizing Union Carbide's role in these efforts as you requested.

## THE GAS CENTRIFUGE PROGRAM

### Union Carbide Role in the Gas Centrifuge Program

The Nuclear Division of Union Carbide Corporation (UCC-ND) has been a key contractor in the Gas Centrifuge Program since its inception in the early 1960s. As is true for all of our enrichment programs, our gas centrifuge work is conducted under contract to DOE. Currently, our centrifuge activities (Chart 2) involve either a lead or a major support role in almost every aspect of the GCEP project and the advanced gas centrifuge development program. Our principal tasks are (1) the successful transfer of centrifuge technology to the GCEP operating contractor (Goodyear Atomic Corporation) and the centrifuge manufacturers (Boeing, Garrett and Goodyear Aerospace); (2) the engineering design and procurement of some major process building equipment; (3) the selection and testing of candidate advanced gas centrifuge designs in cooperation with the R&D staffs of the other AGC team members, e.g., the centrifuge manufacturers, AiResearch Corporation, the University of Virginia, and Lawrence Livermore and Los Alamos National Laboratories; and (4) the design of the prototype Set IV GCEP machine for qualification and reliability testing.

### GCEP Mission

When the Portsmouth expansion project was authorized and later changed to the gas centrifuge technology, its primary purpose was to provide capacity beyond that available from the improved gaseous diffusion plants to meet the anticipated higher demand for enrichment services.

This followed a four-year period when the government could write no new enrichment contracts because it did not have the authorized capacity to support them. Also motivating the GCEP project in 1977 were some important secondary considerations including the desire to reduce the energy intensiveness of the U.S. enrichment complex by the 1990s and to demonstrate an unambiguous U.S. commitment to deploy the world's best available enrichment technology in the face of rising foreign commercial competition.

Today, the secondary considerations are more compelling than they were in 1977. The long-term uncertainties in our energy availability and cost picture continue to be of concern. Also, as just indicated in the introduction, competition from foreign suppliers for enrichment services has become more significant, emphasizing the importance of maintaining a technical lead. On the other hand, the reduced demand for enrichment services has diminished the need for additional separative capacity beyond that available from the diffusion plants and has therefore caused us to consider using GCEP capacity to replace GDP capacity, if the demand for enrichment services does not rebound in the 1990s.

The decision to adopt the gas centrifuge process as the technology base for the Portsmouth expansion was made because GCEP was more economically attractive than *new* gaseous diffusion capacity. It is also true that GCEP forward costs figured from the end of FY 1982 are likely to be lower than out-of-pocket costs from *existing* diffusion plants in the 1990s if advanced centrifuges are deployed. In this regard, we believe that the forward cost approach is the appropriate basis for evaluating GCEP economics. The fact is that there has already been a significant investment in GCEP. In evaluating alternative future strategies, these unrecoverable sunk costs should be ignored for GCEP just as they are for the GDPs.

By the end of this fiscal year, $1.2 to $1.4 billion will have been spent on the GCEP project, as well as hundreds of millions of dollars in research and development. The current DOE plan calls for the first advanced centrifuge (called Set IV) to have an initial capacity of 1.5 times that of the initial GCEP machine and to be ready for introduction into process building number 3. Our best estimate of the corresponding forward cost to complete GCEP under this plan translates into a forward cost of separative work in the neighborhood of $85/SWU ($60/SWU with interest expensed; both numbers expressed in current year dollars). While these estimates will continue to be refined as the Set IV machine is designed and as GCEP construction proceeds, it is clear that the forward cost of GCEP SWUs with an AGC deployed is already in the neighborhood of probable GDP costs.

## Advanced Gas Centrifuge (AGC) Separative Performance Potential

There is a significant potential for improvement in the gas centrifuge performance beyond that which is now planned for Set IV. Our scientists and engineers have looked at a number of advanced machine candidates and have postulated that, for machines that are generally compatible with the overall GCEP design, a factor even as high as four improvement over the first machine introduced at GCEP may ultimately be possible. Looking realistically at the nearer term, we think a factor of two improvement is demonstrable within the next decade provided we have an aggressive AGC program. The potential for installing higher performance machines during plant construction has been noted. Moreover, the potential compatibility between the current machines and advanced machines offers some other promising opportunities. We note that as the gaseous diffusion technology was maturing, GDP capacity was periodically increased by translating technical improvements into improved hardware which was then implemented in construction projects such as CIP and CUP. This same scenario applies to GCEP, with the added advantage that the number of parallel enrichment cascades and the expected normal centrifuge recycle rate provide more flexibility for introduction of new machines. We project that as the AGC program continues to develop improved machines, these can periodically be incorporated into GCEP as it is cost effective to do so. Under some scenarios, the incremental costs projected for these "Improvement Programs" are competitive with costs projected for AIS. While we recognize that reducing the energy requirements for our enrichment complex and maintaining adequate flexibility to respond to what we hope will be an eventual upturn in the SWU market are very important, we wish to emphasize that the key factor making GCEP economically attractive is the opportunity to incorporate advanced centrifuges.

We would like to conclude our comments on the gas centrifuge by summarizing the status of the AGC. We are making good progress on the Set IV program which we mentioned earlier (initial target of 1.5 times the capacity of the first GCEP machines). In laboratory demonstrations on full-size centrifuges, we have already achieved about half of the initial performance target. We believe this machine can be ready in a time frame which will give DOE the option of implementing its current plan to introduce it beginning with process building number 3 and to retrofit buildings 1 and 2.

## ADVANCED ISOTOPE SEPARATION

Turning now to the AIS program, let us briefly summarize the status. Considerable progress has been made in the last two years in the scientific and early engineering exploration of the Molecular Laser Isotope Separation (MLIS) process, the Atomic Vapor Laser Isotope Separation (AVLIS) process, and the Plasma Separation Process (PSP). The lead laboratories involved, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and TRW, Inc., each with support from Oak Ridge, have added considerably to the process data bases. Engineering work has also been initiated, and many hardware items that would ultimately be required in a production plant are now being tested and used at pre-prototypical or prototypical levels. Rather than describe these activities in detail, however, we will confine our remarks to Union Carbide's role in the AIS program with emphasis on our process evaluation effort, as you requested.

### Union Carbide Role in AIS

UCC-ND has been involved in the AIS program for 10 years, since the program's inception. Our principal activities (Chart 3) include technology development support, engineering, process evaluation, and of greater future importance, engineering development and demonstration.

Technology Development Support. We provide R&D support to all three AIS processes. For the two processes which use uranium metal, AVLIS and PSP, we have responsibility for the uranium handling components and materials technology. For the MLIS process, which uses $UF_6$, we have responsibility for the $UF_6$ handling portions of the process, as well as for some process science tasks.

In our R&D efforts, we have worked with each of the process proponents to support their programs and to help put each process in the best possible competitive position. In addition, our direct involvement in the R&D effort has also provided us with a first-hand "insider's" view of the process technology which has been very beneficial in our evaluation work.

Engineering Support. Over the last 18 months, substantial engineering design activities have begun for the AIS processes. During this period, we completed two major tasks working with each of the laboratories--conceptual designs of the AIS development modules and preconceptual studies of production plants.

The purpose of the development module conceptual designs was to establish an accountable project scope, cost estimate, and schedule for the line item construction project for this important facility. Following process selection, the next task will be to initiate a strong process engineering development and demonstration effort. The principal vehicle for these activities will be the development module, which is planned to be a large-scale, fully integrated prototypical process unit*. Photos of development module scale models are attached (Charts 4, 5, 6).

We continue to believe that, after process selection, the development module will be the most important "next step" in the AIS program. In addition to its crucial process development and technology transfer functions, the development module will provide the basis for evaluating the readiness of AIS for production use. The hard data acquired from development module construction and operation are necessary, in our view, to establish the engineering and economic information with which we can confidently make decisions regarding deployment of AIS in the U.S. enrichment enterprise. This is why we strongly endorse an aggressive development module program aimed at acquiring the necessary experience by the mid to late 1980s, in time for decisions affecting the nature of the U.S. enrichment production effort for the mid-1990s and beyond. We believe the development module project should be initiated soon after process selection.

In addition to the development module conceptual designs, we have also completed preconceptual designs of AIS production plants based on current views of how they might be constructed in the mid-1990s. The principal purpose of these design activities was to provide current engineering and economic data bases for the process evaluations being made in conjunction with the DOE process selection effort. For that reason, special attention was given to good definition of the reference design point economics, as well as to cost scaling relationships applicable to departures from the reference design. Operating costs were also emphasized.

The development module and plant engineering studies represent one of UCC-ND's primary inputs to the DOE AIS process selection. Each of these designs represented a team effort between Union Carbide and the proponent laboratory. For each process, both the development module and plant designs were produced by a joint engineering team and received the review and approval of both UCC-ND and laboratory management. In addition, all of the designs were reviewed by DOE and by the competing laboratories. This high degree of review significantly enhanced the quality of the information.

---

*In addition to the development module, other test hardware will be required during the AIS engineering development and demonstration phases. Also, reevaluation of the MLIS program has recently resulted in a proposal that a lower-cost, smaller-scale "Development Unit" be the next step in that program, if MLIS is selected, with a redefinition of requirements for the development module and a change in its schedule.

AIS Process Evaluation. For 40 years, UCC-ND has conducted technical and economic evaluations of uranium enrichment processes for DOE and its predecessors. Hundreds of processes have been evaluated, including a dozen or so which have been and/or are being used or seriously considered, for use on a production scale. Since our work is in support of the U.S. Government, our objective is to provide information which will help identify the best technology choices for the government program. As a part of this effort, for the last several years we have performed evaluations of AIS technology status and economic potential. This has certainly been one of our most challenging and important evaluation programs. During this period, as more has become known about the AIS processes, we have also continued improving our evaluation techniques. In this regard, we would like to summarize our methodology as you requested.

The objectives of our process evaluations are to:

- Provide credible projections of process economic potential, recognizing the possibility of cost growth and performance shortfalls.
- Assist in the quantification of technical risks.
- Identify high-leverage process features to help focus R&D and engineering efforts.
- Provide differentiation among process options and/or among alternative processes.
- Bench-mark progress.
- Assist in overall program strategic planning.

To help achieve these assessment goals, we generally use two evaluation approaches.

The first approach, a base case approach, is built around performance targets that are established primarily by the proponent laboratories; the associated economic features are estimated by a joint Union Carbide-laboratory effort. The primary advantages of these estimates are that they are extensively analyzed and documented and do help to bench-mark progress over time and to quantify high leverage process features. The base cases do, however, tend to reflect proponents' views of the target economic potential of the process.

We have been conducting and publishing base case estimates of AIS economic potential since 1975. During this period, we became convinced that, while they generated important information, the base cases did not provide a broad enough picture. For technologies still in the development stage, it is difficult to forecast accurately any single set of physics, engineering, and cost parameters applicable to a production plant that is a decade or more away from construction. Typically, cost growth and performance degradation are experienced as a technology matures from the development to the deployment phase. In addition, it is difficult to normalize the relative degree of proponents' optimism when comparing base cases. For these reasons, we have developed and substantially improved a second approach which is an uncertainty assessment technique for projecting the economic potential of the AIS processes and the economic consequences of the status of the technology.

In the uncertainty assessments (Chart 7), we start with the recognition that the best we can do today is project reasonable ranges within which the eventual physics, engineering, and cost parameters are expected to lie. There are, therefore, optimistic and pessimistic possibilities for each parameter. We first focus attention on identifying these ranges. Then, using a probabilistic approach, we put many possible combinations of these basic variables into our process and plant design models. These models are extensive and include the capability of process reoptimization, so that physical reality can be maintained and available design responses can compensate to the extent feasible for unfavorable values of the physics variables. After large numbers of cases have been estimated, ranges are developed for the estimated plant cost, the estimated separative work cost, the estimated power requirement, and so on. We believe these ranges are more appropriate current indicators of process potential than the base case estimates.

We first published results of an uncertainty assessment of the AIS processes in 1979. Since then, we have made considerable progress in upgrading and extending the process models and in acquiring physics, engineering, and cost information. Because the manner in which this information is obtained is so important, we would like to elaborate on this point.

One source of our process models and inputs is our own staff of scientists and engineers. Not only do we draw on our AIS staff, which has been extensively involved in all program activities, but we also rely on experts from other UCC-ND activities to assist in specialized areas. To cite one example, in the case of PSP, we are assisted by scientists from the fusion energy program at the Oak Ridge National Laboratory in areas such as plasma physics, superconducting magnets, and gyrotrons. We draw on the total resources of the Nuclear Division whenever helpful.

In addition to our own resources, we have gone outside to get the best expert help available in key areas. For example, we have used a number of vendor studies and consultants in areas such as laser cost and performance and superconducting magnet costs. Such companies as General Dynamics, General Electric, Westinghouse, Mathematical Sciences Northwest, Inc., and Garrett have been involved. Finally, the most productive source of information has been the laboratories themselves, especially since the initiation of a peer review process.

Since the beginning of the AIS programs, we have, of course, relied on the laboratories for a large portion of the information regarding the processes they were developing. In addition, through the technical exchanges within this competitive program, the laboratories' knowledge and opinions regarding their competitors' processes have grown. Full advantage of this resource was taken beginning in 1980 when a formal peer review was initiated for the Laser Isotope Separation processes. In 1981, this was expanded to include PSP. This peer review process has been extremely valuable. The organizations involved have formed excellent peer review teams. During the peer review process, many important issues have, of course, been raised. Subsequently, most of them have been addressed either experimentally or analytically. The issues have either been resolved or, in the event of unresolved disagreement, defined explicitly and quantified. As a result, we believe DOE now has a good basis for evaluating the significant technical issues relative to AIS and the impact of the process uncertainties.

In summary, the peer review process has been a key activity for the AIS program, providing a mechanism for focusing efforts and debate on key technical issues in the true scientific manner. In addition, the peer review has obviously been an especially valuable source of information for our evaluation effort. During the peer review, we have worked closely with the laboratories in developing our process models and engineering data bases, and these themselves have undergone extensive peer review.

Our approach to uncertainty assessment has complemented the peer review process very well. Looking at physics, cost, and engineering parameters as ranges rather than as single points allows a balanced approach which considers both the proponents' views and the critics' views when establishing the optimistic and pessimistic limits of input variables. We believe our approach to uncertainty assessment is a good basis for estimating the comparative economic potential for the AIS processes in a manner which fairly reflects unknowns and risks (Chart 8). As with any such estimate, however, these projections do not tell the whole story. We have made many such estimates, and there are always changes from the previous cases as new technical and engineering information is acquired, as the analytical and modeling tools are upgraded, and as the process approaches themselves change. Thus, it is important that the evaulation effort continue to be an ongoing one closely integrated into the total program.

Our current assessments of the economic potential of the three AIS processes have been provided to the DOE as one of their selection inputs. The DOE is currently using the performance and economic models to make its own projections and to assess the economic consequences of the remaining physics and engineering uncertainties for each process from its point of view. We are continuing to provide DOE with evaluation support during the process selection period as it is requested.

## AIS Process Selection

As you know, the AIS process selection decision is scheduled to be made in April 1982. To help establish the technical basis for its decision, DOE established a Process Evaluation Board (PEB). The PEB has been active for several months now, reviewing the various programs and the technical and engineering data. The Board has also participated in some of the peer review meetings. There is, in addition, a set of detailed selection criteria which will be used by the PEB to help rank the processes. We have worked hard to support the PEB's activities in the areas assigned to us.

We believe that the key factors in selecting an AIS process are (a) the adequacy of the scientific and technical data base, (b) the readiness for engineering development, (c) the economic potential, (d) the intrinsic process flexibility and potential for improvement, and (e) the demonstration and deployment plans and their cost. Having carefully thought about these points ourselves, we agree with DOE that a process selection should be made now (Chart 9). We believe the benefits will be much greater if we move forward expeditiously with a single process that is ready to take the next step. This will accelerate the engineering demonstration of an AIS process at a funding level consistent with current projections of the DOE budget. We believe an AIS selection can be made with acceptable risk and that this action is consistent with the national objective of having the U.S. continue as the world leader in enrichment technology.

## Synergism of AIS and SIS Programs

We are aware of discussions about the AIS and SIS (Special Isotope Separation) programs and how they might interrelate. The whole justification for the AIS program is the benefit of substantially lower uranium enrichment costs; therefore, we strongly believe that the process which is best in this context for uranium enrichment should be selected in the AIS program. Similarly, we would argue that the best process for SIS be selected on the basis of the SIS program objectives. If the same process were best for both applications and if there were important elements of that process common to both programs, then the resulting synergism would be a special bonus, enhancing the technical focus and cost effectiveness of the total effort.

## ENRICHMENT ENTERPRISE STRATEGIC PLANNING

In addition to the AGC and AIS work we have summarized in this statement, Union Carbide has also provided input to DOE over the years to help in its enrichment planning activity. Many complicated issues are involved with respect to both enrichment demand and supply. We have developed and used models which allow DOE's enrichment planning to be cognizant of the rest of the nuclear fuel cycle. These models and computer programs have been developed or acquired and modified to best fit DOE's enrichment planning needs.

The main point we would like to emphasize is that these models are detailed, realistic tools which are regularly updated. The computer codes have served DOE and UCC-ND well in helping to evaluate the impacts of many different factors, including enrichment plant and electric utility operating plans, costs, GDP power availability, capital cost assumptions, and new technologies. Over the last 15 years, we have run literally thousands of cases to define the impact of today's decisions on costs to be experienced decades in the future. Just as technology assessment must be an ongoing activity, the examination of enrichment business strategies must also be dynamic to provide the information necessary for well-informed business decisions.

## CONCLUSIONS

There are many uncertainties that must be taken into account in planning for the future of the enrichment step of the fuel cycle. These uncertainties are both short range and long range and involve both domestic and foreign markets. It is our view, therefore, that those steps should be taken which best preserve our options to continue as the world's leading low-cost supplier of reliable enrichment services. Such an approach, we believe, also best serves the U.S. non-proliferation goals. Based on our view of the enrichment situation as presented in this statement, we offer these conclusions and recommendations:

1. We should continue to go forward with the construction of GCEP with the objective of having the first two buildings on line by the late 1980s. We should maintain viable plans and preserve the option to have the six additional buildings on line by the mid-1990s.

2. We should continue to push hard on the development of the Set IV improved GCEP machine with the objective of having it qualified and ready for installation in process building number 3, as well as having it ready for retrofitting in buildings 1 and 2. The Set IV AGC program continues to look very attractive both from the standpoint of its high benefit-to-cost ratio and from its strategic value in providing an important alternative to gaseous diffusion capacity if electric energy costs rise or if there are power availability problems for the diffusion plants.

3. At the same time, funding support should be provided to capitalize on the good potential for even more advanced centrifuge technology with a goal of making much better Set IV units available for production use in the 1990s. Our current view of the economic potential of these machines suggests that with a strong but reasonable development effort they could be competitive with an AIS process in the same time frame. The country's enrichment program in the 1990s will benefit by pursuing advanced AGC and AIS technologies to the point of comparative evaluation in the late 1980s.

4. Accordingly, we urge that the AIS process selection decision be made on the present schedule. We feel that sufficient information for a choice has been made available to the PEB and we endorse and support the selection approach being followed by DOE. The selection is needed now in order to apply development resources to the best advantage.

5. In that regard, we strongly recommend proceeding with the development module and the supporting engineering development program for the selected AIS process. This is the reasonable next step which must be taken in order to provide the information needed to determine what role AIS can play in the future enrichment enterprise in the U.S. AIS has the potential for providing the U.S. with the world's best, lowest

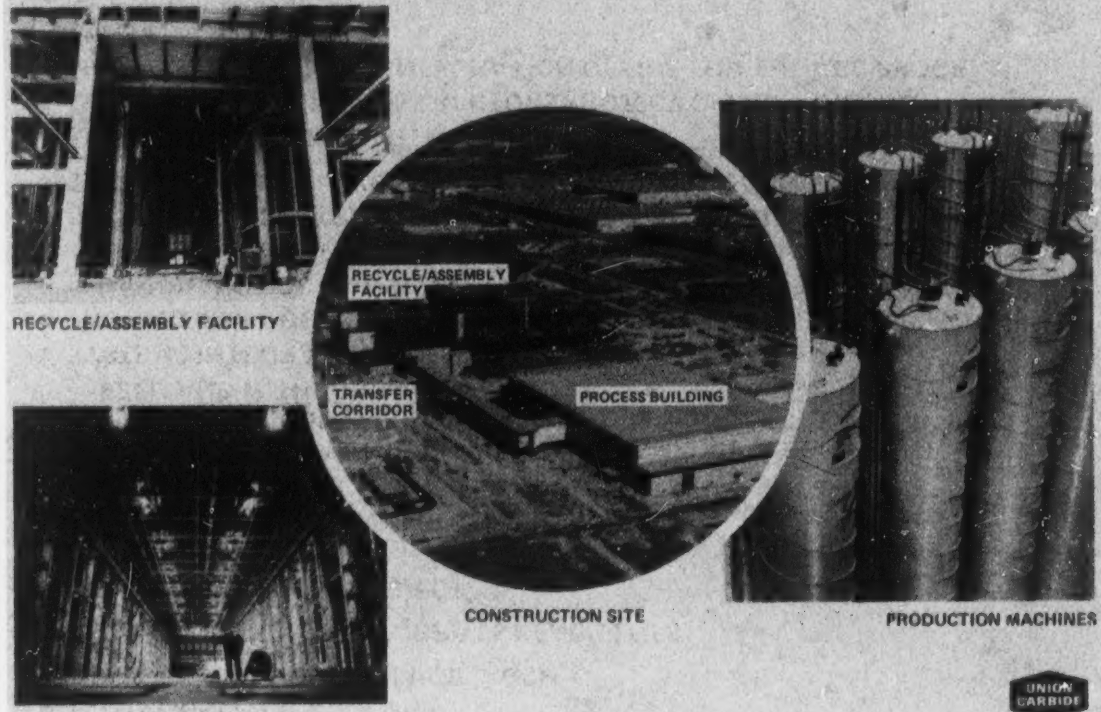
cost enrichment technology, but if this step is not taken in a timely manner, AIS cannot be ready on a schedule which will allow it to compete with AGC for deployment in the 1990s.

6. We again endorse and urge that innovative marketing of U.S. enrichment services be pursued in the foreign market. It is the best way to build credibility as a supplier and to reduce motivation for proliferation by other nations. In addition, it will be of substantial economic benefit to the U.S.

7. Studies of enrichment enterprise strategies should be updated continually to reflect accurately the current projections of market, technology, and economics. Only through such studies of alternative enrichment business scenarios can data be provided for management decisions which use the many available options to best advantage. Current studies continue to show that the benefits of deploying advanced enrichment technologies in the 1990s are substantial and amply justify the recommended research, development, and demonstration investments.

DWG. NO. K/G-82-1646

## GCEP CONSTRUCTION STATUS - SPRING, 1982


RECYCLE/ASSEMBLY FACILITY
RECYCLE/ASSEMBLY FACILITY
TRANSFER CORRIDOR
PROCESS BUILDING
CONSTRUCTION SITE
PRODUCTION MACHINES
PROCESS BUILDING

UNION CARBIDE

Chart 1

DWG. NO. K/G-82-1667

# PRINCIPAL UNION CARBIDE ROLES IN CENTRIFUGE PROGRAM

- MAJOR ROLE IN RESEARCH AND DEVELOPMENT
  - INITIAL GCEP TECHNOLOGY
  - ADVANCED GAS CENTRIFUGE (AGC)
- DESIGN/OPERATION OF MAJOR TEST FACILITIES
- MAJOR ROLES IN GCEP PROJECT
  - CONCEPTUAL DESIGN
  - SYSTEMS REQUIREMENTS DOCUMENTATION
  - TECHNICAL SUPPORT
  - ENGINEERING RESPONSIBILITY FOR MAJOR PROCESS EQUIPMENT (PROCESS BUILDING EQUIPMENT/SERVICE MODULE/RECYCLE/ FEED AND WITHDRAWAL)
  - SYSTEMS INTEGRATION SUPPORT
  - PROCUREMENT RESPONSIBILITY FOR MAJOR PROCESS EQUIPMENT (HANDLING EQUIPMENT/VALVES/CONTROLS/DRIVE SYSTEMS/RA SPECIAL ITEMS/SPECIAL MATERIALS)
  - SUPPORT DOE CENTRIFUGE PROCUREMENT ACTIVITIES
  - TESTING AND QUALIFICATION OF PRODUCTION CENTRIFUGES
- PROGRAM/PROJECT MANAGEMENT SUPPORT
  - MANAGE OPERATING CONTRACTORS PROJECT OFFICE FOR GCEP
  - MANAGE TECHNOLOGY INTEGRATION OFFICE FOR THE AGC PROGRAM

UNION CARBIDE

Chart 2

DWG. NO. K/G-82-1487-R1

## PRINCIPAL UNION CARBIDE ROLES IN AIS PROGRAM

- ASSESSMENTS OF STATUS AND ECONOMIC POTENTIAL OF AIS TECHNOLOGIES
- R&D SUPPORT TO EACH PROCESS
  - AVLIS & PSP
    - URANIUM HANDLING TECHNOLOGY
    - MATERIALS SCIENCE
  - MLIS
    - SPECTROSCOPY
    - POST-PHOTOLYSIS CHEMISTRY
    - $UF_6$ HANDLING TECHNOLOGY
- CONCEPTUAL ENGINEERING FOR DEVELOPMENT MODULE AND PLANT
- PROCESS SCALE-UP, ENGINEERING, DEMONSTRATION, AND DEPLOYMENT

UNION CARBIDE

Chart 3

DWG. NO. K/G-82-1643

# AVLIS DEVELOPMENT MODULE

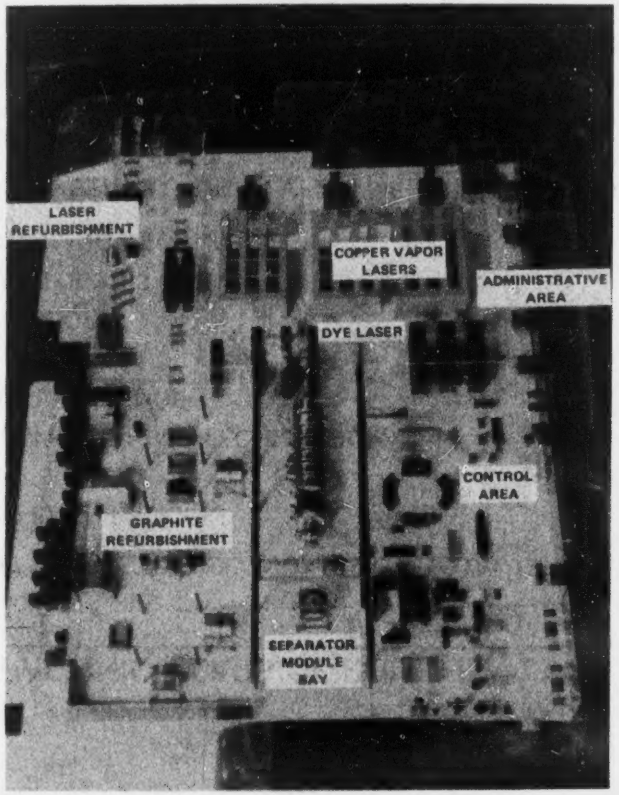
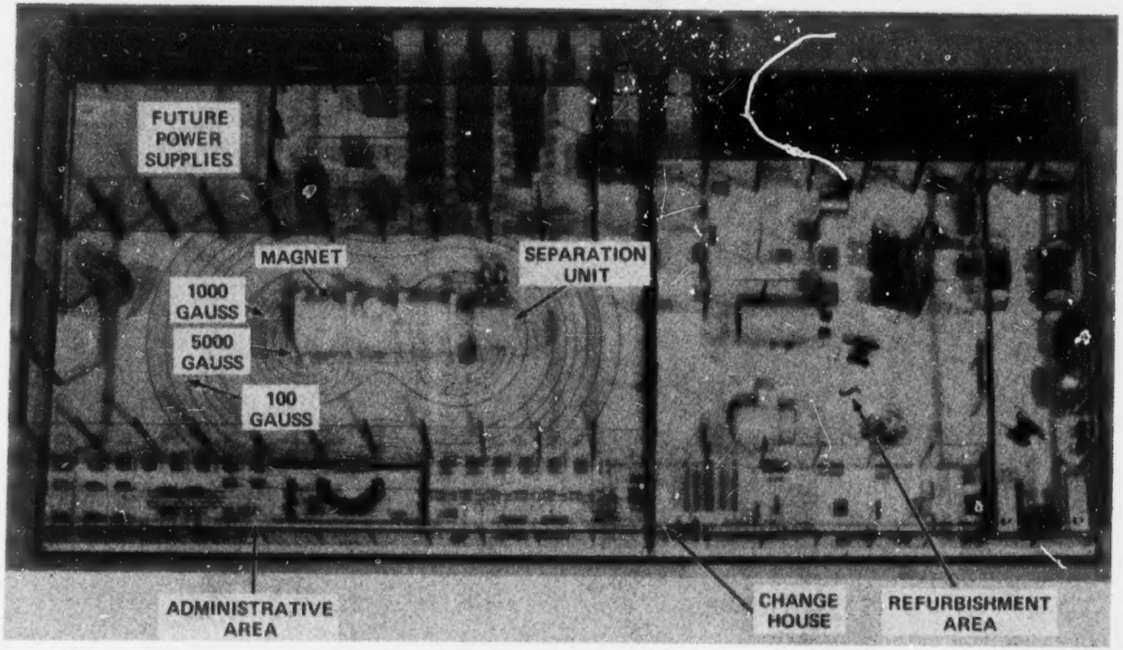

LASER
REFURBISHMENT
COPPER VAPOR
LASERS
ADMINISTRATIVE
AREA
DYE LASER
CONTROL
AREA
GRAPHITE
REFURBISHMENT
SEPARATOR
MODULE
BAY

Chart 4

DWG. NO. K/G-82-1645

**TRW**

# PSP DEVELOPMENT MODULE


FUTURE
POWER
SUPPLIES
MAGNET
SEPARATION
UNIT
1000
GAUSS
5000
GAUSS
100
GAUSS
ADMINISTRATIVE
AREA
CHANGE
HOUSE
REFURBISHMENT
AREA

UNION CARBIDE

Chart 5

Los Alamos

DWG. NO. K/G-82-1644

## MLIS DEVELOPMENT MODULE

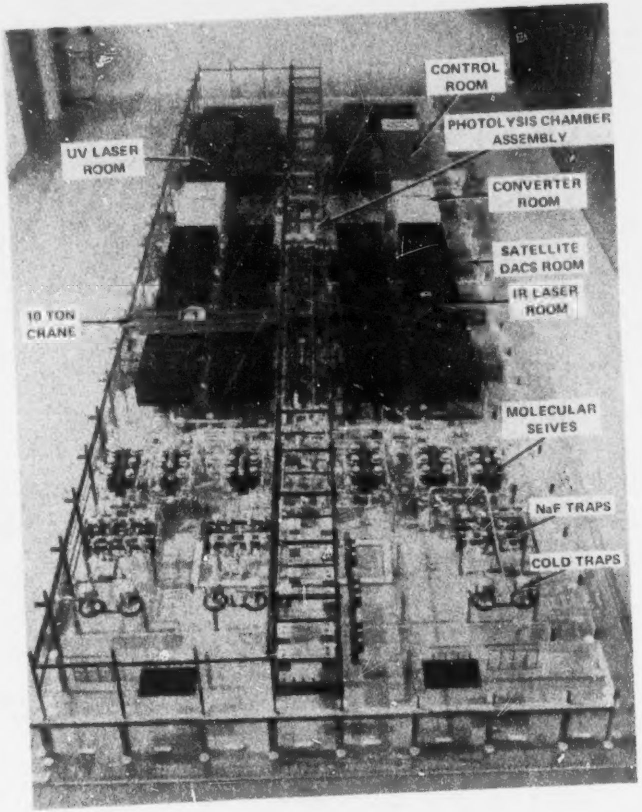

CONTROL ROOM
PHOTOLYSIS CHAMBER ASSEMBLY
UV LASER ROOM
CONVERTER ROOM
SATELLITE DACS ROOM
IR LASER ROOM
10 TON CRANE
MOLECULAR SEIVES
NaF TRAPS
COLD TRAPS

Chart 6

UNION CARBIDE

DWG. NO. K/G-82-1058-R1

# UNCERTAINTY ASSESSMENT OVERVIEW

PURPOSE: PROVIDE CREDIBLE PROJECTIONS OF FUTURE POTENTIAL OF TECHNOLOGIES PRIOR TO THEIR COMPLETE DEMONSTRATION

## PRIMARY REQUIREMENTS

- MUST REPRESENT UNCERTAINTIES
  - RANGES ON TECHNOLOGY AND COST INPUTS MORE REALISTIC AT THIS STAGE THAN SINGLE NUMBERS
  - LEADS TO RANGES FOR PROJECTIONS
- MUST MAINTAIN PHYSICAL REALITY WHEN COMBINING VARIABLES
  - REQUIRES DETAILED PROCESS MODELS, COST-SCALING INFORMATION, AND REOPTIMIZATION ROUTINES

## PRIMARY LIMITATIONS

- VALIDITY LIMITED WHEN THE PHYSICAL PROCESS ITSELF CANNOT BE ADEQUATELY REPRESENTED

## NOTE

- FORMAT IS WELL-SUITED TO PEER REVIEW PROCESS. IT ENABLES PRO AND CON ARGUMENTS TO BE WEIGHED. OPTIMISTIC AND PESSIMISTIC VIEWS OF ULTIMATE OUTCOMES OF PHYSICS, ENGINEERING AND COST INPUTS CAN BOTH THEN BE REPRESENTED

UNION CARBIDE

Chart 7

DWG. NO. K/G-82-1492-R1

# AIS PROCESS UNCERTAINTY ASSESSMENT SUMMARY

- TECHNIQUE IS WELL-SUITED FOR PROJECTING POTENTIAL OF TECHNOLOGIES WHICH, BECAUSE THEY ARE NOT YET FULLY DEMONSTRATED, HAVE SIGNIFICANT UNCERTAINTIES IN PHYSICS, ENGINEERING, AND COST
- TECHNIQUE IS BASICALLY LIMITED BY EXTENT TO WHICH THE PHYSICAL PROCESS CAN BE DESCRIBED
- CURRENT VERSIONS
  - CONTAIN EXTENSIVE ECONOMIC AND PERFORMANCE MODELS – THESE HAVE BEEN PEER REVIEWED
  - INVOLVE INPUTS DEVELOPED FROM DETAILED PEER REVIEW DISCUSSIONS
  - CONTAIN ENGINEERING AND COST DATA BASED ON CURRENT LARGE PLANT DESIGNS
  - ARE GOOD COMPARATIVE ANALYSES OF THE PROCESSES, REFLECTING INTRINSIC PROCESS DIFFERENCES AND RISKS
  - ARE SUBJECT TO CHANGE AS NEW INFORMATION IS OBTAINED

Chart 8

DWG. NO. K/G-82-1490-R1

# AIS PROGRAM SUMMARY:
## MARCH 31, 1982

- EXCELLENT PROGRESS HAS BEEN MADE AT EACH LABORATORY – PROGRAMS HAVE FOCUSED ON SIGNIFICANT ISSUES
- THE PEER REVIEW PROCESS HAS BEEN OF GREAT BENEFIT
  - INTENSE REVIEWS BY COMPETENT EXPERTS – ADVOCATES AND CRITICS
  - SEPARATED KEY ISSUES FROM PHANTOM ISSUES, QUANTIFIED PRESENT LIMITS OF UNCERTAINTIES
  - FOCUSED EXPERIMENTAL ACTIVITY ON MAJOR ISSUES
  - PROFESSIONALLY, RESPONSIBLY HANDLED
- A GOOD PROCESS SELECTION DECISION CAN BE MADE AS SCHEDULED IN MID-FY 1982
  - ADEQUATE SCIENTIFIC DATA BASE
  - GOOD ENGINEERING STUDIES
  - GOOD TECHNICAL EVALUATIONS
  - BUDGET CONSTRAINTS ALSO ARGUE FOR MID-FY 1982 SELECTION
- A GOOD BASIS AND INCENTIVE EXIST FOR INITIATING WORK ON AIS DEMONSTRATION AFTER SELECTION
  - DEVELOPMENT MODULE DESIGNS
  - PROGRAM PLANS
  - OPPORTUNITY TO REALIZE BENEFITS OF HAVING THE BEST ENRICHMENT PROCESS IN THE 1990s

UNION CARBIDE

Chart 9

ROBERT MERRIMAN
Director of Enrichment Technology
Union Carbide Corporation, Nuclear Division

Robert Merriman was born in Knoxville, Tennessee, in 1941. He received his B.S. degree in chemical engineering in 1963 from Vanderbilt University, and his M.S. (1966) and Ph.D. (1975) degrees in the same field from The University of Tennessee.

Dr. Merriman began his career in 1963 with Union Carbide Corporation, Nuclear Division, at the Oak Ridge Gaseous Diffusion Plant. He has held several positions, including Development Engineer (1963) and Chemical Process Development Section Head (1968) at Oak Ridge; Superintendent of the Planning and Technical Support Division (1972), Manager of the Plant Engineering Division (1974), and Manager of Engineering and Technical Services (1976) at the Paducah Gaseous Diffusion Plant; and Director of the Enrichment Technology Division at Oak Ridge (1977). He was appointed to his present position in 1981 and is responsible for Union Carbide's activities in support of DOE programs in development and technical support for the gaseous diffusion, gas centrifuge, and advanced isotope separation processes.

He has been involved in a variety of chemical process development activities related to isotope separation, nuclear fuel reprocessing, nuclear waste disposal, and special material production. He is a recipient of The University of Tennessee Outstanding Engineering Alumnus Award (1979). He is a member of Tau Beta Pi and of the American Institute of Chemical Engineers.

Mr. VOLKMER. Yes, I have a question, Dr. Merriman. If there was a delay in making a choice—even though I think it is going to be made this coming month, in April—would it delay the deployment of future full-scale production plans?

Dr. MERRIMAN. In my opinion, it certainly would.

Mr. VOLKMER. Would it be on a basic month-by-month equivalent? Let us say it was delayed for a year; would it delay the production for a year, do you anticipate?

Dr. MERRIMAN. I think that is certainly the minimum case. I think that given the funding constraints that see in the near term, it is questionable if we could retain a viable program across the board without a selection.

Mr. VOLKMER. With the funds we have, we are almost going to have to go to one. We cannot continue on with three.

Dr. MERRIMAN. I agree. I think that both the technical status and the benefits, as well as the economic realities, argue for that selection strongly.

Mr. VOLKMER. What additional development costs on AIS will have to be met before the selection of an AIS process could be made on the basis of full production costs, compared to advanced gas centrifuge technology? How far down the line do we have to develop it before we know?

Dr. MERRIMAN. Certainly we have ahead of us in AIS a very considerable effort involving the scale-up of hardware, the integration of hardware, and the testing of production-size hardware to get good reliability data, good cost data, and good maintenance data, good operating data.

This development module that I mentioned is the primary vehicle with which we will get that kind of information. It is anticipated that that development module will cost something in the neighborhood of $175 million and come on line in the late 1980's.

Mr. **Volkmer**. That is the construction cost?

Dr. **Merriman**. That is just the construction cost.

Mr. **Volkmer**. What about the engineering and operating costs?

Dr. **Merriman**. With the additional R&D costs required to support the total program, the estimates are more in the neighborhood of $500 million by the late 1980's. So it is only after that length of time and that significant investment, tackling those substantial problems, that we believe we will have the hard engineering and cost data that would allow one to realistically and confidently project what role AIS should play in the enrichment picture.

Mr. **Volkmer**. With regard to the gas centrifuge, this would be at about the same time we were completing, hopefully, the first two buildings; is that right?

Dr. **Merriman**. That is correct.

Mr. **Volkmer**. At about that same time we would be able to have more information to determine whether or not the AIS technology will actually be competitive?

Dr. **Merriman**. That is correct. And I might add that, in that same timeframe, we would expect also to be seeing the products of the advanced gas centrifuge development program.

Mr. **Volkmer**. Fine.

If there were funds available for, say, two processes, would you prefer to have two processes? If we had sufficient funds in the budget, should we proceed down the line to develop two instead of one?

Dr. **Merriman**. Given what we know today, I would believe that, to the extent funds are available, they should be applied to a single process to get better answers for it sooner rather than distributing the funds——

Mr. **Volkmer**. Let us say we had additional funds—somewhere we found additional money—and we could have enough money for the development of two processes. Suppose that instead of a total funding of $500 million, we say that we can provide $1 billion for this AIS development. What would be your answer?

Dr. **Merriman**. My recommendation would be that, considering the fact that we have a strong advanced gas centrifuge potential, we should pick the single best AIS process and try to go with it—try to get it on its feet to compete with the centrifuge in the late 1980's.

Mr. **Volkmer**. You have commented on the country's experience in uranium enrichment and problems with competing with others now who are getting into it also. Mr. Vanstrum, in testimony before the subcommittee in September 1979, said—this goes back a ways, but still I think it is appropriate today:

> Based on our experience in uranium enrichment, we regard the application of international safeguards to the GCEP with some apprehension in the area of specific details of implementation. * * *. We are, however, concerned about potential risk of the dissemination of enrichment technologies as a byproduct of international inspections.

Do you still have any of these apprehensions?

Dr. **Merriman**. We continue, as do others who work in this area, to have apprehensions about the applications of safeguards. Certainly, this depends on the details of the specific strategies.

We do continue to support realistic safeguards at enrichment plants. In this context, we have evaluated a range of inspection strategies for GCEP in cooperation with DOE and other Government contractors. These strategies have covered a wide range of scenarios, including those that involve only marginal technology risk and others that perhaps pose more concerns.

In our opinion, the key issue is whether the technology risks are balanced by the safeguards benefits, and this of course is more of a policy issue than it is a technology issue. The balance does, however, depend very much on, again, the specific details of the selected or negotiated inspection strategies as well as the ability of the international organization to extend and apply in a broader sense a desirable precedent that might be set at GCEP to other foreign facilities.

I might conclude by saying that, at the present time, I understand that these details are being considered by the Department of Energy and the policy decisions are being made there at this time.

Mr. **Volkmer**. How are we insuring that sensitive technology being employed at GCEP is being protected?

Dr. **Merriman**. We are fully extending the classic measures, primarily the classification of sensitive information, maintaining good security procedures, and in this regard even including classified procurements of sensitive components.

Mr. **Volkmer**. Do all personnel have to meet those classification requirements also?

Dr. **Merriman**. That is the current policy.

Mr. **Volkmer**. Yes. How do you view the proposal—which I am sure you are familiar with—of Australia attempting to work with some of our contractors and others throughout the world, but especially ours, as far as this technology problem is concerned? Do you see some transfer problems there—problems with the technology information that is classified—if there was an arrangement with Australia for production of the gas centrifuge?

Dr. **Merriman**. That is of concern. I think appropriate intergovernmental agreements would have to be secured that would protect the classified information. I think certainly we have provided information to DOE on several of those points.

I guess our broad feeling about all of these foreign projects is that we would much rather be selling SWU's to the rest of the world than seeing other countries build capacity.

Mr. **Volkmer**. All right. If GCEP is limited to, say, the first two buildings—2.2 million SWU's in capacity. What would be the cost of producing a SWU, according to your calculations, and when would this be competitive with gaseous diffusion technology?

Dr. **Merriman**. I do not have a precise answer. These calculations in my statement apply to eight buildings—we could provide the numbers for two buildings later.

Mr. **Volkmer**. Could you provide it at a later date by writing to the subcommittee?

Dr. **Merriman**. Certainly.

Mr. **Volkmer**. I appreciate it.

[The information referred to follows:]

Since the GCEP project was planned as an eight-building project, it is difficult without further details and study to do forward cost economic calculations based on two buildings. The cost depends on the exact spending pattern up to the time the decision was made to stop with two buildings and on the timing of this decision. For the case where such a decision was made at the end of 1982, the forward cost to complete two buildings of GCEP and retrofit with Set IV centrifuges to provide 3.3 million SWU/yr capacity is about $115/SWU.

Mr. VOLKMER. I believe in your statement you stated that there will be improvements made in the gas centrifuge technology, with 50 percent improvement, et cetera, and that you could even improve on that. Are you sure in your own mind that this technology is not being oversold and that these goals will be accomplished?

Dr. MERRIMAN. I would like to say that, in this particular case, we do have many years of experience in the centrifuge, many machine years of operation, a significant amount of material has been processed, and we do understand the scaling laws with a high degree of confidence, and we do understand the important cost factors very well.

The long-term advanced centrifuge program, like any advanced technology program, is going to be a tough program. It will be amply challenging of the best that we and our other associates have to field in the way of a technical team. But taking a realistic look, we believe that it is a credible projection. We believe that the projections are very credible, given a commitment to an energetic program.

Mr. VOLKMER. I would like to have an overview of some of your economic analyses with regard to the proper timing of introduction of advanced enrichment technologies into the uranium enrichment enterprise. At present we have gaseous diffusion, but we also see a possible decline in the amount of enriched uranium that may be needed by 1990. The question is, if projections for needed enrichment of uranium decline, or continue to decline, what would be the point at which we would say that we really do not need the GCEP?

Dr. MERRIMAN. Our view of that situation, again, emphasizing the uncertainties in electric energy costs, the uncertainties in electric energy availability, the potential for improvements in the gas centrifuge—our overall view is that the gas centrifuge plant should be viewed, at this point in time, as the baseload of the U.S. enrichment enterprise in the 1990's. That is, so long as there was a need for the 8.8 to 13.2 million SWU's, then we should preserve the option of having that facility on line in that time frame to displace gaseous diffusion capacity, which might be under tremendous economic pressure or even under pressure from an availability standpoint due to electric energy problems at that point in time.

So, basically, our current view is that having the centrifuge come on line in the mid-1990's, having the option of additional centrifuge capacity, and/or AIS capacity to be deployed in that same time frame is a good strategy for the country to be following right now.

Mr. VOLKMER. Let us say we go to the 8.8 million SWU GCEP, and let us say that the demand is only a third of that. We should still do it?

Dr. MERRIMAN. If the total demand was below the nominal capacity of GCEP, then this would signify serious problems with and raise questions about our total nuclear program. But above the 8 million SWU level, we would recommend pursuing some centrifuge capacity, because we think it is attractive for the reasons I mentioned earlier.

Mr. VOLKMER. About how many years out can you accurately project demand, given the number of reactors that we have operating, et cetera, and projected foreign enrichment capacity? Ten years out? Five years out?

Dr. MERRIMAN. Let me qualify my remarks by saying that we are not in the forecasting business. I think we are all well aware of the current curtailments in nuclear programs. I believe the Department of Energy tries to make projections extending out to the year 2000.

Mr. VOLKMER. We all know how those go.

Dr. MERRIMAN. Yes, sir.

Mr. VOLKMER. Let us say that sometime in the future, whether it is the year 1990, or the year 1995, or 2000, we decide to go to a thorium fuel cycle. Which of the technologies we are pursing today would be applicable?

Dr. MERRIMAN. The thorium fuel cycle under some conditions requires no enrichment, per se. There is a chemical separation that is sufficient to separate the fertile thorium from the fissionable uranium-233. For multiple exposure recycles, however, isotopic separation for clean-up on products such as uranium-232, uranium-234, and uranium-236 might be elected and certainly the advanced isotope separation technologies.

Mr. VOLKMER. These would be the ones that would be most applicable, if any?

Dr. MERRIMAN. That is correct.

Mr. VOLKMER. The advanced isotope separation technologies?

Dr. MERRIMAN. The advanced isotope separation methods generally appear to be applicable to those kinds of separations.

Mr. VOLKMER. All right.

Mr. Lowery.

Mr. LOWERY. Thank you, Mr. Chairman.

I have a brief statement, and then I would like to ask some questions.

Mr. VOLKMER. All right; go ahead. I recognize you for your statement. Do you wish to read it or just have it placed in the record?

Mr. LOWERY. Let me read it, if I may, because I would like some response from the panel of witnesses.

Since uranium enrichment activities represent the largest single item in our budget, this is an important subject. When enrichment capacity became available for civilian nuclear power, the United States provided 100 percent of the world's enrichment needs. However, in 1967, France decided to break the United States monopoly in enrichment.

France initiated the formation of an international corporate group. In 1974 this organization began construction of a gaseous diffusion plant in France. This plant is now operating at a level of 8 million SWU's, and when completed this year it will have a capacity of 10.8 million SWU's per year.

At the same time as France was setting up its uranium enrichment organization, British, Dutch, and German companies established a joint venture of their own by international treaty. Centrifuge facilities have already been built by both the British and the Dutch in their countries, and the Germans are in the process of building a new plant.

The U.S.S.R. markets enrichment services through its own totally government-owned and operated organization. Their gaseous diffusion plants provide about 3 million SWU's per year to free world countries. They have not been aggressively marketing their enrichment services since their capacity is apparently full contracted.

Recently, other countries have been moving into the enrichment arena, including Japan, Australia, Brazil, and South America.

These international developments have combined to have an impact on the U.S. enrichment capacity. The Department of Energy continues to provide for all of U.S. enrichment needs, but the U.S. share of the foreign market has clearly declined. The U.S. presently has contracts for about 20 countries, which accounts for about 30 percent of the free world market.

The loss of the foreign market means that these revenues will not be available to offset the costs of providing enrichment services, which otherwise would benefit U.S. taxpayers through lower energy costs. The declining international market share also hurts the U.S. balance of trade both directly and indirectly.

I am now concerned that the controversies over the future direction of the U.S. uranium enrichment program will result in decisions that further jeopardize our ability to be a reliable supplier of enriched uranium. Not only would this be harmful to our U.S. industry and our national security, but it will mean even less U.S. control over nonproliferation issues.

Could the panelists respond?

Dr. MERRIMAN. I think the gentleman made a very strong statement, with which I agree. I think those concerns are very realistic and ones that we would share.

Mr. VOLKMER. That pretty well follows your statement in response to my question about GCEP and the need for GCEP then?

Dr. MERRIMAN. We want to see the country be active in the nuclear business and continue to be a world leader in uranium enrichment, as we have been for many, many years.

I think GCEP, which is an unambiguous commitment to the best technology in the world today—that is in hand today—is a strong element of that effort.

Mr. VOLKMER. Does the gentleman from California have any questions?

Mr. LOWERY. Yes, thank you.

Dr. Merriman, has DOE lost enrichment business to foreign competition as a result of lower prices or as a result of anticipated price increases by DOE?

Dr. MERRIMAN. It is difficult to understand all the factors involved. My own belief is that the primary reasons for our decline in market share were not price related but loss of credibility as a reliable supplier of enrichment services.

I think there was a 4-year period in the mid-1970's while the direction of the U.S. enrichment business was being debated, where we were not even able to open our order books and take on new customers. In that period, the projects that you referenced in your statement were born and having potential customers tied into their own enrichment plants certainly diminishes our ability to capture that market segment.

I believe the overriding factor has been overall credibility as a reliable supplier, as opposed to price. I think certainly in the long term we want to insure that we do offer the best technology and the best price, so that we do not suffer that disadvantage.

Mr. LOWERY. But we need some degree of reliability?

Dr. MERRIMAN. Yes, sir.

Mr. LOWERY. Today's testimony has included statements that the ability of DOE to competitively market U.S. enrichment services internationally should be improved. What specific recommendations would you make?

Dr. MERRIMAN. We have been very pleased to see that in the last few years DOE has been very visible in the marketplace. My specific recommendations are along the lines of continuing to examine the types of contracts that are offered to our customers to see whether they can be more individualized and tailored more precisely to the needs of specific customers on a customer-by-customer basis, so that we perhaps can offer special incentives to special customers, as opposed to just a standard set of terms and conditions and prices that are applicable to everyone.

I think the flexibility of the contract is one productive area that perhaps we can continue to explore.

Mr. LOWERY. Instead of take it or leave it, we want to work with you on meeting your specific needs?

Dr. MERRIMAN. I think that is a standard sales approach.

Mr. LOWERY. That is in the private sector. It has been: You sell, or you perish.

Do you see the United States restoring this degree of credibility and reliability in the international markets as it relates to enrichment? Is that a perception, that we have found our way again?

Dr. MERRIMAN. I am an optimist. I believe there are a lot of people committed to making that happen, and I believe that some of the actions we are taking now may well provide the basis for turning the corner.

I think that if we can see an upturn in the worldwide nuclear business in the 1990's, given some of the current initiatives, we will be out there in the marketplace and hopefully be seen in a better light than perhaps we were a few years ago. I am optimistic.

Mr. LOWERY. But you think the jury is still out?

Dr. MERRIMAN. We are not signing new contracts with any great degree of onslaught right now, although we have, as I understand it, had some optimistic developments, particularly most recently with Egypt; I believe they signed a letter of intent with DOE some time back.

Mr. LOWERY. But we have still not made up for the lost ground in recent years?

Dr. MERRIMAN. Certainly not.

Mr. LOWERY. Thank you, Dr. Merriman. Thank you, Mr. Chairman.

Mr. VOLKMER. Dr. Merriman, I have one additional question in regard to the gas centrifuge, I asked the previous panel—I believe you may have heard it—the question with regard to private involvement. I agree with their answer as far as the gas centrifuge is concerned. What about the private enterprise being able to get into uranium enrichment once we have demonstrated advanced isotope separation successfully? Say the technology proves out; have you any ideas on whether the private sector should get into this?

Dr. MERRIMAN. I think that at the point in the program that you mentioned—namely, when the hard data are in from the development module that it would be appropriate certainly to look at that option. I think it might be an attractive option, given the right set of security guarantees.

Mr. VOLKMER. We would still have to have legislation?

Dr. MERRIMAN. You would want to provide for the protection of sensitive technology, but I think those sorts of things can be worked out. I would endorse considering that option at that point in time, very definitely.

Mr. VOLKMER. I have no further questions. Do the staff members have any questions?

Does the gentleman from California have any additional questions?

Mr. LOWERY. We have two questions the staff would like to get on the record.

Mr. VOLKMER. All right.

Ms. FREIWALD. You testified that the advanced centrifuge technologies could be competitive with the AIS process in the 1990's. Is that to imply that you believe that we should focus the enrichment program on the more advanced centrifuge technologies and not on the AIS technologies at all?

Dr. MERRIMAN. No. My belief is that we should pursue both of those very strongly, because we do not know precisely how either is going to come out at the present time. We should pursue both of them through the 1980's very strongly, very competitively, and make that judgment at that time.

Mr. VOLKMER. Excuse this interjection just a moment on that answer, because it concerns me just a little bit, and I want you to clear up your statement.

You said you do not know how either of those technologies are going to turn out. This bothers me a little bit. You are not telling us that you do not think that the gas centrifuge will work?

Dr. MERRIMAN. No. As I said, we have a high degree of confidence in the success of those programs, but knowing just what the deployment strategy should be depends on a lot of details.

Mr. VOLKMER. Are you talking one as opposed to the other?

Dr. MERRIMAN. I am talking about trading off advanced centrifuge Set V and Set VI technology against AIS. This tradeoff depend upon the relative outcomes, and until we go further in both programs—AGC and AIS we will not know those precisely.

Mr. VOLKMER. But you are sure, at least for the centrifuge program, that it is proven as a technology, as far as you are concerned?

Dr. MERRIMAN. As I indicated, we have a high degree of confidence that that program is very realistic and can result in significant advancements in the technology. It will require a determined program. We are going to have to work the problem, but we think it can be done and think that good teams are assembled to do that.

Mr. **Volkmer**. Thank you.

Do you have another question?

Ms. **Freiwald**. Yes, sir.

You also testified that the GCEP forward costs are likely to be lower than the out-of-pocket costs for the existing diffusion plants if advanced centrifuge are deployed. Does this mean that the present centrifuge machines are not cost competitive with the diffusion plants?

Dr. **Merriman**. Rather than try to make a case on some precise prediction of what the future electricity prices might be from gaseous diffusion plants, which is the key factor involved my view is to say that with the set IV machine for a credible range of electric energy cost in the 1990's, GCEP will be lower cost. My concern is that we avoid developing a strategy that is precisely dependent upon any single set of economic projections. Those are always subject to change.

What I do believe is that, with the set IV machine, over a range of possible outcomes for electric energy costs in the 1990's, the forward cost of GCEP is a good deal.

Ms. **Freiwald**. What about set III?

Dr. **Merriman**. Set IV just gives us more assurance, relative to set III that we can have that project be economically attractive over a range of gaseous diffusion plant energy costs.

Mr. **Lowery**. Thank you, Mr. Chairman.

My apologies to the witnesses for my tardiness. I have got another committee meeting going simultaneously which I do need to get back to, but thank you, Dr. Merriman, for your testimony, and thank you, Mr. Chairman.

Mr. **Volkmer**. Thank you.

Dr. Merriman, we have no further questions. Now we will adjourn the hearing this morning. Thank you very much.

[Whereupon, at 11:16 a.m., the hearing was recessed, to reconvene subject to the call of the Chair.]

[Appendix II, questions and answers submitted for the record, and appendix III, additional material submitted for the record follows:]

# APPENDIX II

## QUESTIONS AND ANSWERS SUBMITTED FOR THE RECORD

DON FUQUA, FLA., CHAIRMAN

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD BOUQUARD, TENN.
JAMES J. BLANCHARD, MICH.
DOUG WALGREN, PA.
RONNIE G. FLIPPO, ALA.
DAN GLICKMAN, KANS.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
RICHARD C. WHITE, TEX.
HAROLD L. VOLKMER, MO.
HOWARD WOLPE, MICH.
BILL NELSON, FLA.
STANLEY N. LUNDINE, N.Y.
ALLEN E. ERTEL, PA.
BOB SHAMANSKY, OHIO
RALPH M. HALL, TEX.
DAVE MC CURDY, OKLA.
MERVYN M. DYMALLY, CALIF.

LARRY WINN, JR., KANS.
BARRY M. GOLDWATER, JR., CALIF.
HAMILTON FISH, JR., N.Y.
MANUEL LUJAN, JR., N. MEX.
HAROLD C. HOLLENBECK, N.J.
ROBERT S. WALKER, PA.
EDWIN B. FORSYTHE, N.J.
WILLIAM CARNEY, N.Y.
MARGARET M. HECKLER, MASS.
F. JAMES SENSENBRENNER, WIS.
VIN WEBER, MINN.
JUDD GREGG, N.H.
RAYMOND J. MC GRATH, N.Y.
JOE SKEEN, N. MEX.
CLAUDINE SCHNEIDER, R.I.
JIM DUNN, MICH.
BILL LOWERY, CALIF.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

HAROLD P. HANSON
EXECUTIVE DIRECTOR

PHILIP B. YEAGER
ROBERT C. KETCHAM
REGINA A. DAVIS
MARTHA KREBS
GEORGE S. KOPP
JOHN V. DUGAN, JR.
THOMAS H. MOSS
DARRELL R. BRANSCOME
ANTHONY C. TAYLOR
THOMAS P. GRUMBLY

GERALD E. JENKS
MINORITY STAFF DIRECTOR

April 23, 1982

Richard L. Grant, President
Boeing Engineering & Construction,
Southeast, Inc.
P.O. Box 851
Oak Ridge, TN 37830

Dear Mr. Grant:

Thank you for the testimony presented by you on the Department of Energy's Uranium Enrichment Program at the Subcommittee on Energy Research and Production's FY 1983 budget review hearing on March 31, 1982. I would like to supplement the record of the hearing with some additional questions that the Subcommittee has regarding the program.

Mr. Merriman, from Union Carbide, was questioned regarding the relative economics of the Gas Centrifuge Enrichment Project. We are interested in also having your response to the same question that was asked of Mr. Merriman:

> "Union Carbide testified that GCEP forward costs are likely to be lower than the out-of-pocket costs from existing diffusion plants - if advanced centrifuges are deployed. Does this mean that the present centrifuge machines are not cost-competitive with diffusion plants?"

If you have any questions regarding this request, please contact Joyce Freiwald of the Subcommittee staff, at (202) 225-8056.

Sincerely,

Manuel

MANUEL LUJAN, JR.
Ranking Republican Member
Subcommittee on Energy Research
and Production

ML/Fw

*Boeing Engineering & Construction Southeast, Inc.*

767 Mitchell Road
Oak Ridge, Tennessee 37830

JUN 4 1982

June 1, 1982

The Honorable Manuel Lujan, Jr.
Ranking Republican Member
Subcommittee on Energy Research & Production
Rayburn House Office Building, Suite 2321
Washington, D. C. 20515

Dear Sir:

My apologies for the delay in responding to your request for my answer to the same question asked of Dr. Merriman of Union Carbide Corporation Nuclear Division. The question restated and my response follow:

> "Union Carbide testified that GCEP forward costs are likely to be lower than the out-of-pocket costs from existing diffusion plants - if advanced centrifuges are deployed. Does this mean that the present centrifuge machines are not cost-competitive with diffusion plants?"

The usual difficulty with this type of question is the use of terms such as "out-of-pocket costs." Therefore, let me put the costs into perspective in the following way: First, assume that whatever enrichment process we are addressing exists in 1983, and second, that out-of-pocket costs are paid out of the pocket of the clothes we are wearing on the day we must pay. Thirdly, we will always speak of like capacity of each process and assume that the demand exists.

Existing centrifuge machines will result in a plant capacity of 8.8 million SWU. Speaking first to the directly comparable cost of enriching uranium - namely, the power costs and the operating costs (labor and materials), 8.8 million SWU of the centrifuge enrichment would cost about $280 million. Gaseous diffusion in the same quantity will cost $850 million.

If advanced gas centrifuges of the 50% improved variety (Set IV) were being used, the capacity would be 13.2 million SWU at a cost of about $300 million. The cost for 13.2 million SWU of diffusion enrichment would be about $1.275 billion.

If on the other hand, the 100% improved centrifuges were being used, the capacity would be 17.6 million SWU at a cost of about $330 million. 17.6 million SWU of diffusion enrichment would cost about $1.7 billion.

Since you will always receive and pay in the economics environment of the future and since a feel for the magnitudes of uncertainties is important, I have constructed a Table to look at the above cases with different

BE&C
A Subsidiary of The Boeing Company

assumptions about the future. The Table (attached) presents the comparison of centrifuge and diffusion costs (power plus operating) in millions of dollars for one year's production of 8.8M, 13.2M or 17.6M SWUs in the appropriate future year. Numbers are shown for future escalation assumptions for power and inflation to demonstrate the sensitivity of these costs to escalation.

For example, if 8.8 million SWU capacity were the basis and all inflation and power escalation stopped, the cost difference for a year's production would always be $570 million. If on the other hand, the improved 17.6M SWU case were the basis and escalation were to proceed at 12% for power and 8% for inflation, the cost difference in the year 2000 would be $9.75 billion in that year alone.

These cost differences need to be assessed in terms of capital expenditures. For example, let's assume that all original costs for diffusion are forgiven leaving only the $1.5 billion CIP/CUP dollars to repay in 1983 dollars, and that the entire $6.95 billion (1983 dollars) of centrifuge costs must be repaid over a 25 year period. On this basis, 25 years at 8.8M SWU/year for diffusion will cost $22.75 billion, while the centrifuge costs will be $13.95 billion.

All of this is, of course, merely mathematics and we must live in a world of imperfect assumptions. The important feature of the program is, however, the decoupling of future production from both the supply and cost of energy. Escalation will continue to be a part of our nation's economic future; only the degree remains uncertain. The GCEP program will yield lower costs in today's dollars with the present centrifuge machines. The present machines will yield even lower costs relative to diffusion as energy escalation and inflation continue. As indicated by the foregoing numbers, the advanced machines can provide even further significant relative cost reductions.

Please do not hesitate to call if the above requires further clarification, or if I may be of further assistance.

Sincerely,

Richard L. Grant
President

Enclosure

## COMPARISON OF CENTRIFUGE WITH DIFFUSION COSTS
(Cost of Power Plus Operating Costs)

| Year | Escalation | 8.8M SWU | | 13.2M SWU | | 17.6M SWU | |
|---|---|---|---|---|---|---|---|
| | Pwr % / % Infl | GCEP $M | GDP $M | GCEP $M | GDP $M | GCEP $M | GDP $M |
| 1983 | | 280 | 850 | 300 | 1275 | 330 | 1700 |
| 1990 | 6/6 | 420 | 1290 | 450 | 1935 | 480 | 2580 |
| | 8/8 | 480 | 1470 | 510 | 2200 | 550 | 2940 |
| | 10/8 | 490 | 1640 | 525 | 2460 | 565 | 3280 |
| | 12/8 | 500 | 1840 | 540 | 2760 | 580 | 3680 |
| 1995 | 6/6 | 560 | 1720 | 600 | 2580 | 640 | 3420 |
| | 8/8 | 700 | 2155 | 750 | 3230 | 800 | 4310 |
| | 10/8 | 725 | 2620 | 790 | 3930 | 850 | 5240 |
| | 12/8 | 755 | 3190 | 830 | 4780 | 910 | 6380 |
| 2000 | 6/6 | 750 | 2300 | 800 | 3450 | 860 | 4600 |
| | 8/8 | 1030 | 3170 | 1100 | 4750 | 1180 | 6330 |
| | 10/8 | 1080 | 4180 | 1180 | 6270 | 1285 | 8360 |
| | 12/8 | 1160 | 5540 | 1290 | 8210 | 1330 | 11080 |

DON FUQUA, FLA., CHAIRMAN
ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD BOUQUARD, TENN.
JAMES J. BLANCHARD, MICH.
DOUG WALGREN, PA.
RONNIE G. FLIPPO, ALA.
DAN GLICKMAN, KANS.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
RICHARD C. WHITE, TEX.
HAROLD L. VOLKMER, MO.
HOWARD WOLPE, MICH.
BILL NELSON, FLA.
STANLEY N. LUNDINE, N.Y.
ALLEN E. ERTEL, PA.
BOB SHAMANSKY, OHIO
RALPH M. HALL, TEX.
DAVE MC CURDY, OKLA.
MERVYN M. DYMALLY, CALIF.
LARRY WINN, JR., KANS.
BARRY M. GOLDWATER, JR., CALIF.
HAMILTON FISH, JR., N.Y.
MANUEL LUJAN, JR., N. MEX.
HAROLD C. HOLLENBECK, N.J.
ROBERT S. WALKER, PA.
EDWIN B. FORSYTHE, N.J.
WILLIAM CARNEY, N.Y.
MARGARET M. HECKLER, MASS.
F. JAMES SENSENBRENNER, WIS.
VIN WEBER, MINN.
JUDD GREGG, N.H.
RAYMOND J. MC GRATH, N.Y.
JOE SKEEN, N. MEX.
CLAUDINE SCHNEIDER, R.I.
JIM DUNN, MICH.
BILL LOWERY, CALIF.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

HAROLD P. HANSON
EXECUTIVE DIRECTOR

PHILIP B. YEAGER
ROBERT C. KETCHAM
REGINA A. DAVIS
MARTHA KREBS
GEORGE S. KOPP
JOHN V. DUGAN, JR.
THOMAS H. MOSS
DARRELL R. BRANSCOME
ANTHONY C. TAYLOR
THOMAS P. GRUMBLY

GERALD E. JENKS
MINORITY STAFF DIRECTOR

April 23, 1982

Robert W. Clark, President
Goodyear Aerospace Corporation
1210 Massillon Road
Akron, OH 44315

Dear Mr. Clark:

Thank you for the testimony presented by you on the Department of Energy's Uranium Enrichment Program at the Subcommittee on Energy Research and Production's FY 1983 budget review hearing on March 31, 1982. I would like to supplement the record of the hearing with some additional questions that the Subcommittee has regarding the program.

Mr. Merriman, from Union Carbide, was questioned regarding the relative economics of the Gas Centrifuge Enrichment Project. We are interested in also having your response to the same question that was asked of Mr. Merriman:

> "Union Carbide testified that GCEP forward costs are likely to be lower than the out-of-pocket costs from existing diffusion plants - if advanced centrifuges are deployed. Does this mean that the present centrifuge machines are not cost-competitive with diffusion plants?"

If you have any questions regarding this request, please contact Joyce Freiwald of the Subcommittee staff, at (202) 225-8056.

Sincerely,

Manuel

MANUEL LUJAN, JR.
Ranking Republican Member
Subcommittee on Energy Research
and Production

ML/Fw

GOODYEAR AEROSPACE CORPORATION
AKRON, OHIO 44315

PRESIDENT

May 4, 1982

The Honorable Manuel Lujan, Jr.
Subcommittee on Energy Research
and Production
Suite 2321
Rayburn House Office Building
Washington, D.C. 20515

Reference: Your Letter of April 23, 1982

Dear Congressman Lujan:

We have received your referenced letter and are pleased to be able to give you our response to the question that was asked of Mr. Merriman from Union Carbide.

We have reviewed data available to us regarding the GCEP cost projections, and we believe that you can readily verify our response data by direct contact with Mr. Voigt or members of his staff.

The question, as we understand it to be asked, was "Are projected enrichment costs using the present Plc centrifuge competitive with the enrichment costs using the gaseous diffusion plants?"

Our review of the projected cost data indicates that the Plc or present model centrifuges are competitive with diffusion costs when the full 8-building part is completed. This is also assuming today's power costs. When the power costs are increased to project the power costs expected by the time the GCEP plant is actually on line, then the centrifuge enrichment costs are less than the comparable diffusion costs.

The centrifuge cost advantage increases with time since power costs have been increasing at a rate higher than the general inflation rate. When Set IV (advanced centrifuge) machines are phased into the GCEP plant, the cost savings are, of course, substantially greater.

I trust that this reply will help to clarify the confusion that was created by the apparent misunderstanding during the questioning period of the Subcommittee Hearings on March 31. If we can be of any further help, please do not hesitate to contact us.

Sincerely,

Robert W. Clark

e

cc: Ms. Joyce Freiwald
Staff Manager
Committee on Science & Technology
U.S. House of Representatives
Rayburn House Office Building, Room 374
Washington, D.C. 20515

DON FUQUA, FLA., CHAIRMAN
ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD BOUQUARD, TENN.
JAMES J. BLANCHARD, MICH.
DOUG WALGREN, PA.
RONNIE G. FLIPPO, ALA.
DAN GLICKMAN, KANS.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
RICHARD C. WHITE, TEX.
HAROLD L. VOLKMER, MO.
HOWARD WOLPE, MICH.
BILL NELSON, FLA.
STANLEY N. LUNDINE, N.Y.
ALLEN E. ERTEL, PA.
BOB SHAMANSKY, OHIO
RALPH M. HALL, TEX.
DAVE MC CURDY, OKLA.
MERVYN M. DYMALLY, CALIF.
LARRY WINN, JR., KANS.
BARRY M. GOLDWATER, JR., CALIF.
HAMILTON FISH, JR., N.Y.
MANUEL LUJAN, JR., N. MEX.
HAROLD C. HOLLENBECK, N.J.
ROBERT S. WALKER, PA.
EDWIN B. FORSYTHE, N.J.
WILLIAM CARNEY, N.Y.
MARGARET M. HECKLER, MASS.
F. JAMES SENSENBRENNER, WIS.
VIN WEBER, MINN.
JUDD GREGG, N.H.
RAYMOND J. MC GRATH, N.Y.
JOE SKEEN, N. MEX.
CLAUDINE SCHNEIDER, R.I.
JIM DUNN, MICH.
BILL LOWERY, CALIF.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

HAROLD P. HANSON
EXECUTIVE DIRECTOR
PHILIP B. YEAGER
ROBERT C. KETCHAM
REGINA A. DAVIS
MARTHA KREBS
GEORGE S. KOPP
JOHN V. DUGAN, JR.
THOMAS H. MOSS
DARRELL R. BRANSCOME
ANTHONY C. TAYLOR
THOMAS P. GRUMBLY
GERALD E. JENKS
MINORITY STAFF DIRECTOR

April 23, 1982

Mr. William H. Sutton
Garrett Corporation
2525 W. 190 Street
Torrence, CA 90509

Dear Mr. Sutton:

Thank you for the testimony presented by you on the Department of Energy's Uranium Enrichment Program at the Subcommittee on Energy Research and Production's FY 1983 budget review hearing on March 31, 1982. I would like to supplement the record of the hearing with some additional questions that the Subcommittee has regarding the program.

Mr. Merriman, from Union Carbide, was questioned regarding the relative economics of the Gas Centrifuge Enrichment Project. We are interested in also having your response to the same question that was asked of Mr. Merriman:

> "Union Carbide testified that GCEP forward costs are likely to be lower than the out-of-pocket costs from existing diffusion plants - if advanced centrifuges are deployed. Does this mean that the present centrifuge machines are not cost-competitive with diffusion plants?"

If you have any questions regarding this request, please contact Joyce Freiwald of the Subcommittee staff, at (202) 225-8056.

Sincerely,

Manuel

MANUEL LUJAN, JR.
Ranking Republican Member
Subcommittee on Energy Research
and Production

ML/Fw

AiResearch Manufacturing Company

2525 W. 190th St.
Torrance
California 90509
Cable: Garrettair
Torrance

In Reply Refer To:
CCWHS:020:0519

May 19, 1982

Honorable Manuel Lujan, Jr.
Ranking Republican Member
Subcommittee on Energy
Research and Production
House of Representatives
Washington, D.C. 20515

Dear Mr. Lujan:

I appreciate the opportunity to offer additional comments regarding the economic comparisons of uranium enrichment processes as they pertain to the Gas Centrifuge Enrichment Project (GCEP).

The ability to determine the project unit costs of production for any enrichment activity is based upon the thorough visibility of hundreds of cost elements and related data that constitute the basis for computation. The Garrett Corporation identified these elements during our efforts to establish a commercial enrichment venture in 1975. (See attached sheet for partial listing of significant factors)

Union Carbide Corporation has direct access to all of the historical data related to those elements as it pertains to the U.S. Government Enrichment enterprise - past and present; we at Garrett do not.

Taking a purely 'simplistic' approach, however, it is reasonable to make the following comparison:

> If you ignore the sunk cost of past construction, the dominant costs of operating the Gaseous Diffusion Plants (GDP) are related to power. That power cost has been particularly susceptible to inflation, running about 10% above the general rate during the last decade.
>
> On the other hand, the GCEP will use only 5% of the power required by the GDP to produce an equivalent SWU output. Although the ongoing construction costs for GCEP must be included in the forward costs, the overall inflation impact represented by power cost escalation alone will make the GCEP plant cost competitive in time.
>
> Based on the above, the question can best be answered by pointing out that, 1) the Set III centrifuge technology will eventually overtake the gaseous diffusion process from the economic standpoint; 2) creating an advanced machine (Set IV) will accelerate the point of economic crossover; and 3) the additional power plant capacity provided by off-loading the GDP's can be effectively utilized by industrial customers, eliminating the need for construction of new power plants in the near term to serve both needs.

Honorable Manuel Lujan, Jr.
House of Representatives

CCWHS:020:0519
Page 2

We at The Garrett Corporation have dedicated significant amounts of our energy and resources toward the success of the Gas Centrifuge machine over the past 21 years. Your personal interest in attempting to fully understand and evaluate the true impact of the GCEP project is most gratifying.

Please feel free to call on me at your convenience if I can be of any further assistance to the subcommittee during your deliberations.

Very truly yours,

AIRESEARCH MANUFACTURING COMPANY
A Division of The Garrett Corporation

Wm H. Sutton
William H. Sutton
Program Manager
Commercial Gas Centrifuge

WHS:REJ:tds

Attachment

# REQUIRED ECONOMIC DATA FOR PROGRAM

- GEOGRAPHIC LOCATION
- DEBT LEVEL
- EQUITY LEVEL
- TAX STRUCTURE (GEOGRAPHIC LOCATION)
  - FEDERAL
  - STATE
  - LOCAL
  - SALES TAX
  - INVENTORY TAX
- INSURANCE
  - GENERAL
  - BUILDERS RISK
  - PROPERTY
  - NUCLEAR
  - WORKMAN'S COMPENSATION
- OWNER CONTROL WRAPUP AND CONVENTIONAL LIABILITY
  - BUSINESS INTERRUPTION
  - FEED INSURANCE
- STARTUP PROFILES
- DEPRECIATION APPROACH AND ASSET LIFE
- MANPOWER AVAILABILITY (GEOGRAPHIC LOCATION)
- LABOR RATES
- UTILITY RATES
- PRICING STRATEGY
- COST OF MONEY
- METHOD OF PROCURING MONEY (GOVERNMENT VS PRIVATE)
- INVESTMENT TAX CREDIT RATE
- ROYALTY FEES
- CONTRACT LIFE
- ESCALATION PROFILE
- RATE OF RETURN ON INVESTMENT
- SPECIAL OVERHEAD CONSIDERATIONS
- TRANSPORTATION
- INVENTORY PHILOSOPHY
- ACCOUNTING
- FINANCIAL AND BUSINESS POLICY

GARRETT

A-22974

# APPENDIX III

## ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD

### PREPARED TESTIMONY OF SENATOR HOWARD M. METZENBAUM
BEFORE
THE SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
MARCH 31, 1982

MADAME CHAIRMAN, I APPRECIATE THE OPPORTUNITY TO COMMENT ON THE DEPARTMENT OF ENERGY'S URANIUM ENRICHMENT ACTIVITIES AND THE ROLE THE GAS CENTRIFUGE ENRICHMENT PLANT (GCEP) PROGRAM SHOULD PLAY IN OUR NATION'S ENERGY POLICY.

IN 1972, THE UNITED STATES CONTROLLED FULLY 100 PERCENT OF THE FREE WORLD'S NUCLEAR FUEL MARKET. TODAY, OUR MARKET SHARE HAS DWINDLED TO LESS THAN 35 PERCENT. THIS EROSION TOOK PLACE BECAUSE THE UNTED STATES WAS NO LONGER PERCEIVED AS A COMPETITIVE AND RELIABLE SUPPLIER OF ENRICHED URANIUM SERVICES. OUR NATION VACILLATED ABOUT WHETHER OR NOT TO MOVE FORWARD WITH MORE ENERGY EFFICIENT AND COST COMPETITIVE TECHNOLOGY SUCH AS GCEP.

THIS VACILLATION SENT A MESSAGE TO FOREIGN GOVERNMENTS. AND SOME COUNTRIES THAT DEPEND ON NUCLEAR POWER AS THEIR BASIC ENERGY SOURCE BEGAN TO SEEK OUT NEW SUPPLIERS SUCH AS JAPAN AND FRANCE. OTHER COUNTRIES, NOTABLY WEST GERMANY, BRITAIN AND THE NETHERLANDS, FORMED THEIR OWN PRODUCTION CONSORTIUM.

AS A RESULT OF OUR INDECISION, THE UNITED STATES LOST MORE THAN $29 BILLION IN FOREIGN TRADE. AND OUR COUNTRY LOST SOMETHING EVEN MORE IMPORTANT --OUR POSITION OF AUTHORITY IN FURTHERING OUR NATIONAL GOALS OF NUCLEAR NON-PROLIFERATION. THE LOSS OF FOREIGN CONTRACTS FOR ENRICHED URANINUM SERVICES CREATES IMMEDIATE FINANCIAL PROBLEMS FOR OUR ECONOMY. BUT THE LOSS OF OUR ABILITY TO EXERT INFLUENCE OVER DEVELOPING NATIONS TO ENSURE THAT NUCLEAR POWER IS USED ONLY FOR CIVILIAN PURPOSES MAY IN THE LONG RUN BE A FAR MORE SERIOUS THREAT TO OUR NATIONAL SECURITY INTERESTS.

TODAY, WE FACE A CRITICAL CHOICE. ARE WE WILLING TO ALLOW OUR WORLD MARKET SHARE TO DECLINE FURTHER, OR WILL WE MOVE TO REGAIN OUR POSITION OF PREEMINENCE AS A COMPETITIVE AND RELIABLE SUPPLIER OF ENRICHED URANIUM SERVICES?

OUR POSTION WILL DOUBTEDLY CONTINUE TO DIMINISH IF WE CONTINUE TO RELY SOLELY ON THE EXISTING GASEOUS DIFFUSION TECHNOLOGY FOR ENRICHED URANIUM PRODUCTION. THAT TECHNOLOGY IS EXTREMELY ENERGY INTENSIVE, REQUIRING MASSIVE AMOUNTS OF ELECTRICITY TO PERFORM THE SEPARATIVE WORK UNITS. THE COST OF GENERATING ELECTRICITY IN THE UNITED STATES IS RISING FASTER THAN THE OVERALL RATE OF INFLATION. AS A RESULT, THE INCREASING PRODUCTION COSTS FROM EXISTING GASEOUS DIFFUSION FACILITIES MEANS THAT WE ARE LOSING OUR ABILITY TO SELL

ENRICHED URANIUM SERVICES AT A COMPETITIVE PRICE IN THE WORLD MARKETPLACE. IF WE ARE UNABLE TO REDUCE OUR COSTS AND SELL ENRICHED URANIUM AT A LOWER PRICE, WE WILL BE THREATENED WITH THE LOSS OF MORE CONTRACTS IN FUTURE YEARS.

THE ALTERNATIVE IS CLEAR. REGAINING OUR POSITION AS A RELIABLE SUPPLIER AND AS A LEADER IN PROMOTING NUCLEAR NONPROLIFERATION DOES NOT REQUIRE A CRASH PROGRAM. THE UNITED STATES IS ON THE VERGE OF BRINGING ON LINE GAS CENTRIFUGE TECHNOLOGY THAT WILL REDUCE BY 90 PERCENT THE AMOUNT OF ENERGY REQUIRED TO PERFORM THE SEPARATIVE WORK UNITS REQUIRED TO ENRICH URANIUM. THESE DRAMATIC ENERGY SAVINGS WILL PERMIT THE DEPARTMENT OF ENERGY TO REDUCE ITS PRICES, THEREBY INCREASING OUR COMPETITIVENESS IN THE WORLD MARKETPLACE.

THE GAS CENTRIFUGE TECHNOLOGY HAS BEEN THROUGHLY TESTED. IT HAS BEEN DEMONSTRATED TO BE THE ONLY TECHNOLOGY AVAILABLE TO SIGNIFICANTLY REDUCE PRODUCTION COSTS. CONSTRUCTION OF A PLANT TO BRING THIS TECHNOLOGY INTO COMMERICAL PRODUCTION IS ALREADY UNDER WAY AT THE DEPARTMENT OF ENERGY'S GCEP FACILITY AT PORTSMOUTH, OHIO. AND THE ONLY ROADBLOCK TO RETURNING THE UNITED STATES TO A POSITION AS A COMPETITIVE AND RELIABLE SUPPLIER OF ENRICHED URANIUM SERVICES IS FULL CONGRESSIONAL FUNDING FOR GCEP TO ENSURE THAT THE ENTIRE FACILITY IS COMPLETED ON SCHEDULE.

WE CANNOT AFFORD ANOTHER BUDGET CUT LIKE THE ONE CONGRESS IMPOSED IN FY 1981, WHEN GCEP'S FUNDING WAS CUT IN HALF. THAT WAS A CLASSIC CASE OF A FALSE ECONOMY. THE CONGRESS "SAVED" $170 MILLION THAT YEAR. BUT IN DOING SO, CONGRESS DELAYED GCEP'S COMPLETION FOR A FULL YEAR. THAT DELAY ADDED MORE THAN $200 MILLION TO THE OVERALL COST OF COMPLETING THE PROJECT DUE TO INCREASED CAPITAL COSTS, HIGHER INTEREST PAYMENTS AND INFLATION. TAXPAYERS ALSO WERE FORCED TO SHOULDER THE BURDEN OF OPERATING THE COSTLY EXISTING GASEOUS DIFFUSION FACILITIES FOR ANOTHER YEAR. AND TENS OF MILLIONS OF DOLLARS IN FOREIGN ORDERS WERE LOST AS CONTRACTS EXPIRED AND WERE NOT RENEWED. IN ALL, THE $170 MILLION CONGRESS "SAVED" WILL END UP COSTING THE AMERICAN TAXPAYER $700 MILLION.

TO CONSIDER ANOTHER BUDGET CUT FOR GCEP WOULD BE ONCE AGAIN TO ENGAGE IN THE KIND OF "PENNY WISE, POUND FOOLISH" POLICYMAKING OF WHICH THERE HAS BEEN TOO MUCH IN CONGRESS IN RECENT YEARS. AS IN FISCAL YEAR 1981, THE UNITED STATES WILL STAND TO LOSE MILLIONS OF DOLLARS IN FOREIGN ORDERS. WE WILL CONTINUE TO RELY ON THE WASTEFUL AND OUTDATED DIFFUSION TECHNOLOGY WHILE POSTPONING THE 90 PERCENT ENERGY SAVINGS THAT GCEP WOULD BRING.

BUT THIS TIME, THE BUDGET CUT AND RESULTING DELAYS WOULD INEVITABLY DISCOURAGE THE PRIVATE COMPANIES INVOLVED IN THIS PROGRAM FROM MAKING FURTHER INVESTMENTS NEEDED TO MOVE GCEP AHEAD. EXECUTIVES IN THESE COMPANIES WILL ASK THEMSELVES WHETHER THE CONGRESS

REMAINS COMMITTED TO THE PROJECT OR WHETHER WE WILL OPT FOR AN UNPROVEN TECHNOLOGY THAT IS YEARS AWAY FROM COMMERICAL DEVELOPMENT. INEVITABLY THOSE BUSINESSMEN WILL QUESTION THE WISDOM OF COMMITTING FURTHER CAPITAL RESOURCES FOR A PROJECT THAT MAY TURN OUT TO BE NIPPED IN THE BUD.

MADAME CHAIRMAN, THE CHOICE IS CLEAR. WE CAN PROVIDE FULL FUNDING FOR GCEP AT A LEVEL OF $613 MILLION, AS RECOMMENDED BY THE ADMINISTRATION. THAT CHOICE WILL ALLOW GCEP TO MOVE AHEAD ON SCHEDULE OR WE CAN CUT GCEP'S BUDGET AND TELL THE DEPARTMENT OF ENERGY TO CONTINUE TO ATTEMPT TO COMPETE IN THE WORLD MARKETPLACE USING THE EXISTING GASEOUS DIFFUSION TECHNOLOGY. THAT CHOICE WILL MEAN HIGHER COSTS FOR ENRICHED URANIUM SERVICES, HIGHER ENERGY BILLS, LOST CONTRACTS TO FOREIGN SUPPLIERS, AND A LESSENED ROLE IN ENSURING THAT OUR NUCLEAR NONPROLIFERATION GOALS ARE MET.

I URGE THE MEMBERS OF THE HOUSE TO SUPPORT FULL FUNDING FOR THE GAS CENTRIFUGE ENRICHMENT PROGRAM.

# FISCAL YEAR 1983 DEPARTMENT OF ENERGY BUDGET REVIEW

---

## THURSDAY, MAY 20, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
*Washington, D.C.*

The subcommittee met, pursuant to call, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Marilyn L. Bouquard (chairman of the subcommittee) presiding.

Mrs. **Bouquard**. The subcommittee will come to order.

The rules of the House require that we take a recorded vote to close the session to the public, and accordingly the clerk will call the roll.

Ms. **Shisler**. Mrs. Bouquard?

Mrs. **Bouquard**. Aye.

Ms. **Shisler**. Mr. Lujan?

Mr. **Lujan**. Aye.

Ms. **Shisler**. Mr. Roe?

[No response.]

Ms. **Shisler**. Mr. Forsythe?

[No response.]

Ms. **Shisler**. Mr. Ottinger?

[No response.]

Ms. **Shisler**. Mr. Lowery?

[No response.]

Ms. **Shisler**. Mr. Young?

[No response.]

Ms. **Shisler**. Mr. Goldwater?

[No response.]

Ms. **Shisler**. Mr. Lundine?

[No response.]

Ms. **Shisler**. Mr. Hollenbeck?

[No response.]

Ms. **Shisler**. Mr. Flippo?

[No response.]

Ms. **Shisler**. Mr. Volkmer?

[No response.]

Ms. **Shisler**. Mr. Wolpe?

[No response.]

Ms. **Shisler**. Mr. Fuqua?

[No response.]

Ms. **Shisler**. Mr. Winn?

[No response.]

Mrs. BOUQUARD. The clerk will report.

Ms. SHISLER. Two ayes, no nays.

Mrs. BOUQUARD. According to the vote, the hearing is declared closed.

Good morning ladies and gentlemen. Today the subcommittee will review the Department of Energy's fiscal year 1983 budget request for the advanced isotope separation program. This will complete the subcommittee's review of the Department's fiscal year 1983 budget request for all the programs under its jurisdiction.

Three AIS technologies have been under development within the DOE program for a number of years: (1) the atomic vapor laser isotope separation process being developed by Lawrence Livermore National Laboratory; (2) the molecular laser isotope separation process being developed by Los Alamos National Laboratory; and (3) the plasma separation process being developed by TRW, Inc.

These three options have been pursued in parallel within the Department's uranium enrichment program because they all have shown the potential to produce enriched uranium at a low-production cost compared to current gaseous diffusion and gas centrifuge technologies.

Work on these technologies is also being funded under DOE's special isotope separation program because of their potential to separate isotopes of plutonium.

This past April 30 the Department announced that it had selected the atomic vapor laser process for large-scale engineering development and demonstration as a result of an in-depth, 7-month review of the three competing technologies by its Process Evaluation Board. The Department also announced that it would continue to provide support for research on the plasma separation process, with program levels subject to availability of funds.

I want to welcome back today Mr. Bill Voigt, Acting Director of the Office of Uranium Enrichment and Assessment. Mr. Voigt will be accompanied by Dr. James Leiss, chairman of the AIS Process Evaluation Board and Associate Director, Office of High Energy and Nuclear Physics; and Dr. Norton Haberman, leader of the Office of Uranium Enrichment and Assessment's technology development team.

We expect these gentlemen will address in detail the selection process, the remaining technology issues, and the funding required to meet program schedules and milestones.

I am also pleased that Mr. Herman Roser, DOE's Assistant Secretary for Defense Programs, can join us here today to discuss the Department's special isotope separation program. We hope that you, Mr. Roser, as well as Mr. Voigt, can advise the subcommittee on how best scarce resources can be used to maximally benefit both programs.

I would ask that each of you gentlemen give your testimony in turn, and then we will ask you questions after you have finished.

Mr. Voigt, please proceed.

We are very happy that Mr. Lujan is with us. He is, as you now, the ranking Republican on this committee, and he certainly serves this committee well and with distinction.

Mr. Lujan.

Mr. LUJAN. Thank you, Madam Chairman.

We have all watched with interest the development of the advanced isotope separation technologies, which offer significant advantages over other uranium enrichment technologies.

Selecting one technology from the three under consideration has been, or course, a very difficult decision, especially since new experimental data and new design concepts were continually being generated. This meant the basis for the assessment was, of course, constantly changing.

About $300 million have been invested in AIS over the past 8 years. I expect it will take another $300 million before we have a full-scale production plant. Should the selected process fail to meet expectations after scaling up to the intermediate level demonstration module, the expenditures of about $1 billion will be lost.

For this reason, the small additional investment in funding to support a backup technology and an experimental physics program will not only prevent the other two doors from being completely closed, but provide insurance for our investment.

Mr. Winn earlier cited the ERAB and GAO reports, both advocating as delay in the decision. I should also mention that the ERAB report discussed the possibility of limited funding with work focusing on the most pressing technical problems "selected by DOE management after considering those identified by the Process Evaluation Board."

The ERAB report also stated that the AIS decision "should not be made independently from the plutonium isotope program." Although this was not a consideration in DOE's decision, I am delighted that we will have a chance to discuss this aspect today with my old friend Herman Roser. I am looking forward to discussing these issues today, Madam Chairman.

Thank you very much.

Mrs. BOUQUARD. Thank you very much, Mr. Lujan.

Mr. Voigt, you may proceed with your testimony.

## STATEMENT OF WILLIAM R. VOIGT, JR., DIRECTOR, OFFICE OF URANIUM ENRICHMENT AND ASSESSMENT, DEPARTMENT OF ENERGY, ACCOMPANIED BY DR. JAMES E. LEISS, CHAIRMAN, ADVANCED ISOTOPE SEPARATION PROCESS EVALUATION BOARD AND ASSOCIATE DIRECTOR, OFFICE OF HIGH ENERGY AND NUCLEAR PHYSICS, AND DR. NORTON HABERMAN, LEADER, TECHNOLOGY DEVELOPMENT TEAM, OFFICE OF URANIUM ENRICHMENT AND ASSESSMENT

### STATEMENT OF WILLIAM R. VOIGT, JR.

Mr. VOIGT. Thank you, Madam Chairman.

I would like to thank you for the opportunity to discuss the Department of Energy's advanced isotope separation program. Specifically, we will discuss our budget request for fiscal year 1983, the results of the Process Evaluation Board's assessment of the three competing technologies, and the plans we have for the future development of the program.

As you are aware, and so indicated in your opening statement, the Department recently announced the selection of the atomic vapor laser isotope separation process for large-scale engineering development and demonstration.

In addition, the Department will continue to provide limited support for research on the plasma separation process, subject to availabilty of funds.

This announcement was the final step in a process that began about 18 months ago when the AIS program office, with the active participation of the four major program participants, began developing detailed selection criteria.

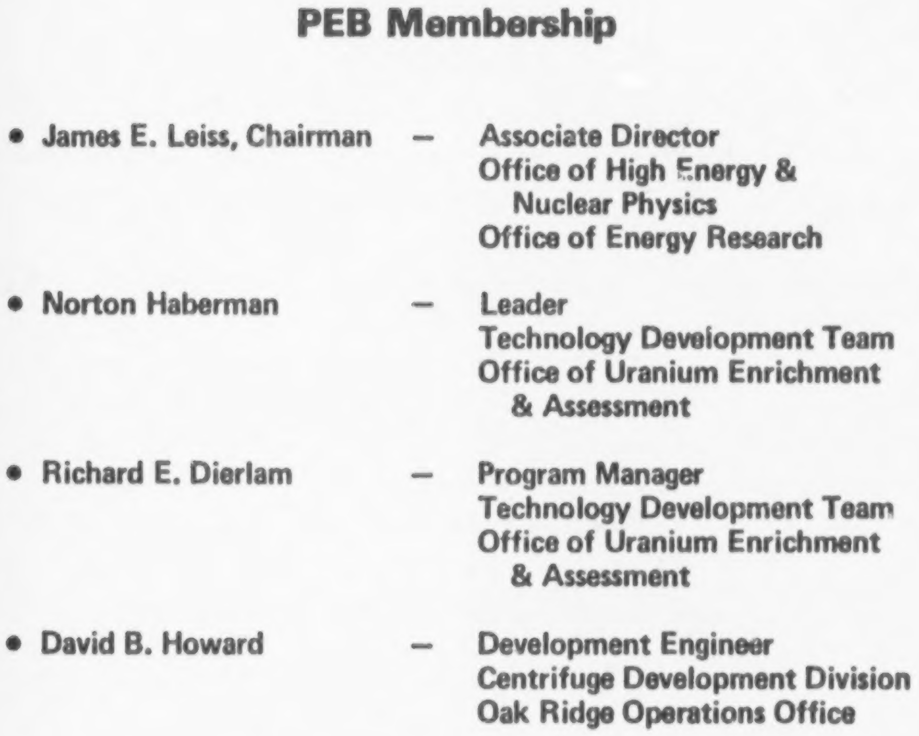
## Purpose of Process Evaluation Board

- **Conduct In-Depth Review and Evaluations of Each of the Three Competing Processes**
- **Recommend Which Process Should Proceed Toward Full-Scale Engineering Development**

Chart 1

In July 1981, I established the Process Evaluation Board (chart 1) and chartered it to first conduct in-depth reviews and evaluations of each of the competing processes, and then recommend which process should proceed toward full-scale engineering development.

I at this time introduce the members of the Process Evaluation Board, whose names are listed on Chart 2.



## PEB Membership

- **James E. Leiss, Chairman** – Associate Director
  Office of High Energy &
  Nuclear Physics
  Office of Energy Research
- **Norton Haberman** – Leader
  Technology Development Team
  Office of Uranium Enrichment
  & Assessment
- **Richard E. Dierlam** – Program Manager
  Technology Development Team
  Office of Uranium Enrichment
  & Assessment
- **David B. Howard** – Development Engineer
  Centrifuge Development Division
  Oak Ridge Operations Office

Chart 2

Dr. James Leiss is Chairman of the Board and Associate Director of High Energy and Nuclear Physics within the Office of Energy Research. The three other members include Dr. Norton Haberman, who is my leader of the technology development team within my office; Dick Dierlam, who is program manager of the technology development team, again within my office, and David Howard, who is the development engineer from Oak Ridge, in the great State of Tennessee.

Mrs. Bouquard. Very well taken, Mr. Voigt.

## PEB Focus

- **What Are the Prospects for Successful Engineering Development?**
- **Is the Technical Base Adequate to Proceed to the Next Step in Process Scaleup?**
- **Do the Projected Economics of the Technology Meet the AIS Program Goals?**
- **Is There Sufficient Flexibility Within the Technology and in the Design of Large Facilities Sufficient to Overcome Potential Problems?**
- **Does the Proposed Development Module Provide Adequate Confidence That Will Enable DOE to Commit to the Deployment of the Technology?**
- **Are the Program Plans, Schedules, and Costs Realistic?**

Chart 3

Mr. VOIGT. The Process Evaluation Board using the selection criteria as a framework, focused on six issues (chart 3):

First, what are the prospects for successful engineering development?

Second, is the technical base adequate to proceed to the next step in process scale-up?

Third, do the projected economics of the technology meet the AIS program goals?

Fourth, is there sufficient flexibility within the technology, and in the design of large facilities, to overcome potential problems?

Fifth, does the proposed development module provide adequate confidence that will enable DOE to commit to the deployment of the technology?

Sixth, are the program plans, schedules, and costs realistic?

They conducted their assessment through detailed reviews of program documentation, covering such areas as basic science and technology, engineering designs and program plans; visits to all of the sites involved in the program; they have looked at specified risk and economic assessments; and finally, by obtaining information from a detailed "Peer Review," in which each participant critiqued the other two processes in open forum.

I believe, and I am sure that the members of the PEB agree, that this peer review system was essential in assisting the PEB in defining the key technical and engineering issues associated with each of the processes (chart 4).

## Overview of Selection Criteria

- **Design of Plant and Development Module**
- **Process Performance and Scale-Up Risk**
- **Relative Economic Potential**
- **Program Management and Plans**

Chart 4

Using this data, the PEB evaluated each process in terms of the risks associated with scaling the process performance from the existing small-scale experiments to larger plants; the completeness of designs of the development module and production plants; the relative economic potential; and, finally, the quality of the proposed program management and implementation plans.

In my instructions to the PEB, they were to consider only the three competing AIS processes as applied to uranium enrichment. They did not address the applications to the special isotope separation program, nor did they evaluate the AIS technologies against the advanced gas centrifuge program.

With regard to the latter, it is our intent to continue the AGC program and AVLIS technology developments in parallel and make a decision by the end of the decade as to which technology should be used for the next increment of enrichment once the gas centrifuge enrichment plant is completed.

Mrs. BOUQUARD. Would you run that by one more time?

Mr. VOIGT. That we are analyzing AVLIS, which is the selected process, against the advanced gas centrifuge program with the intent of analyzing both of these competing technologies within the framework of building additional new capacity above and beyond GCEP.

Mrs. BOUQUARD. Thank you.

Mr. VOIGT. Before Dr. Leiss discusses the results of the PEB's evaluations, I would like to present the department's request for AIS effort in fiscal year 1983 (chart 5).

ADVANCED ISOTOPE SEPARATION PROGRAM BUDGET

($ IN 000)

| | FY 1982 | | FY 1983 | |
|---|---|---|---|---|
| | BA | BO | BA | BO |
| OPERATING | 79,561 | 81,764 | 30,296 | 27,846 |
| CAPITAL EQUIPMENT | 5,500 | 7,250 | 2,500 | 1,000 |
| CONSTRUCTION | 650 | 1,810 | 1,400 | 350 |
| TOTAL | 85,711 | 90,824 | 34,196 | 29,196 |

Chart 5

You will note there is a decrease of $51 million in the program from fiscal year 1982 to fiscal year 1983. In formulating this budget, we assumed only the selected process would be pursued in fiscal year 1983.

Because of the very recent selection of the AVLIS process and the direction the program will take in order to comply with the recommendations of the PEB and the Department's actions, a detailed program for fiscal year 1983 has not yet been developed.

In regard to the future pace of the AVLIS program, I feel strongly that the process has the potential to produce separative work at low unit costs. However, the PEB raised an issue [deleted] that could potentially have a significant impact on the design of the DM. Therefore, the AVLIS program is being oriented to address this issue so that a basis for finalizing the design is available.

The PEB estimated it could take 18 to 24 months to obtain a definitive answer to this issue. Therefore, until the necessary data is available, it would not be prudent to proceed with the schedule we had previously discussed with this committee. The precise slip in the program is presently uncertain, but the delay may approach 1 year.

I would now like to turn to Jim Leiss, chairman of the Process Evaluation Board, who will present the results of the PEB's evaluations and their recommendations. The charts that Dr. Leiss will use in his testimony before this committee will also be made available for the record.

Following his presentation, we will be pleased to respond to any questions the chairman may have.

Thank you, Madam Chairman.

[The prepared statement of Mr. Voigt follows:]

Statement of
William R. Voigt, Jr.
Director
Office of Uranium Enrichment and Assessment
Office of Nuclear Energy
U.S. Department of Energy
Before the
Subcommittee on Energy Research and Production
Committee on Science and Technology
U.S. House of Representatives
May 20, 1982

I would like to thank you for the opportunity to discuss the Department of Energy's (DOE'S) Advanced Isotope Separation (AIS) Program. Specifically, we will discuss our budget request for FY 1983, the results of the Process Evaluation Board's (PEB's) assessment of the three competing technologies, and the plans we have for the future development of the program.

As you are aware, the Department recently announced the selection of the Atomic Vapor Laser Isotope Separation (AVLIS) process for large-scale engineering development and demonstration. In addition, the Department will continue to provide limited support for research on the Plasma Separation Process (PSP), subject to availability of funds. This announcement was the final step in a process that began about 15 months ago when the AIS Program Office with the active participation of the four major program participants began developing detailed selection criteria (copy attached for the record). In July of 1981, I established the PEB and chartered it to: (Chart 1)

- o Conduct in-depth reviews and evaluations of each of the competing processes, and

B 3178

# Purpose of
# Process Evaluation Board

- Conduct In-Depth Review and Evaluations of Each of the Three Competing Processes
- Recommend Which Process Should Proceed Toward Full-Scale Engineering Development

Chart 1

- Recommend which process should proceed toward full-scale engineering development.

I would like to take this opportunity to introduce the members of the PEB. (Chart 2)

The PEB used the selection criteria as a framework and focused on the following six issues. (Chart 3)

- What are the prospects for successful engineering development?
- Is the technical base adequate to proceed to the next step in process scaleup?
- Do the projected economics of the technology meet the AIS Program goals?
- Is there sufficient flexibility within the technology and in the design of large facilities sufficient to overcome potential problems?
- Does the proposed development module provide adequate confidence that will enable DOE to commit to the deployment of the technology?
- Are the program plans, schedules, and costs realistic?

They conducted their assessment through detailed reviews of program documentation, covering such areas as basic science and technology,

## PEB Membership

- James E. Leiss, Chairman — Associate Director
  Office of High Energy &
  Nuclear Physics
  Office of Energy Research
- Norton Haberman — Leader
  Technology Development Team
  Office of Uranium Enrichment
  & Assessment
- Richard E. Dierlam — Program Manager
  Technology Development Team
  Office of Uranium Enrichment
  & Assessment
- David B. Howard — Development Engineer
  Centrifuge Development Division
  Oak Ridge Operations Office

Chart 2

# PEB Focus

- What Are the Prospects for Successful Engineering Development?
- Is the Technical Base Adequate to Proceed to the Next Step in Process Scaleup?
- Do the Projected Economics of the Technology Meet the AIS Program Goals?
- Is There Sufficient Flexibility Within the Technology and in the Design of Large Facilities Sufficient to Overcome Potential Problems?
- Does the Proposed Development Module Provide Adequate Confidence That Will Enable DOE to Commit to the Deployment of the Technology?
- Are the Program Plans, Schedules, and Costs Realistic?

Chart 3

engineering designs, and program plans; visits to all of the sites involved in the program; preparing specified risk and economic assessments; and, finally, by obtaining information from a detailed "Peer Review" in which each participant critiqued the other two processes in open forum. I believe, and I am sure the members of the PEB agree that this "Peer Review" system was essential in assisting the PEB in defining the key technical and engineering issues associated with each of the processes.

Using this data, the PEB evaluated each process in terms of the risks associated with scaling the process performance from the existing small-scale experiments to larger plants; the completeness of designs of the Development Module (DM) and production plants; the relative economic potential; and finally, the quality of the proposed program management and implementation plans. (Chart 4)

In my instructions to the PEB, they were to consider only the three competing AIS processes as applied to uranium enrichment; they did not address the applications to the Special Isotope Separation (SIS) Program; nor did they evaluate the AIS technologies against the Advanced Gas Centrifuge (AGC) Program. With regard to the latter, it is our intent to continue the AGC and AVLIS technology developments in parallel and and make a decision by the end of the decade as to which technology should be used for the next increment of enrichment once the Gas Centrifuge Enrichment Plant (GCEP) is completed.

Before Dr. Leiss discusses the results of the PEB's evaluations, I would like to present the Department's request for AIS effort in FY 1983. (Chart 5) You will note that there is a decrease of $46 million in the

# Overview of Selection Criteria

- Design of Plant and Development Module
- Process Performance and Scale-Up Risk
- Relative Economic Potential
- Program Management and Plans

Chart 4

# ADVANCED ISOTOPE SEPARATION PROGRAM BUDGET

($ IN 000)

|  | FY 1982 |  | FY 1983 |  |
|---|---|---|---|---|
|  | BA | BO | BA | BO |
| OPERATING | 79,561 | 81,764 | 30,296 | 27,846 |
| CAPITAL EQUIPMENT | 5,500 | 7,250 | 2,500 | 1,000 |
| CONSTRUCTION | 650 | 1,810 | 1,400 | 350 |
| TOTAL | 85,711 | 90,824 | 34,196 | 29,196 |

Chart 5

program from FY 1982 to FY 1983. In formulating this budget, we assumed only the selected process would be pursued in FY 1983. Therefore, DOE's decision to maintain a limited research and development program on the PSP technology will require an adjustment in the budget. In addition, the AVLIS budget for FY 1983 is approximately 20 percent lower than in FY 1982. Therefore, we are currently looking to the possibility of submitting a amended request.

In regard to the future pace of the AVLIS program, I feel strongly that the process has the potential to produce separative work at low unit costs. However, the PEB raised an issue concerning the operation DELETED DELETED that could potentially have a significant impact on the design of the DM. Therefore, the AVLIS program is being oriented to address this issue so that a basis for finalizing the design is available. The PEB estimated it could take 18 to 24 months to obtain a definitive answer to this issue. Therefore, until the necessary data is available, it would not be prudent to proceed with the schedule we had previously discussed with this Committee. The precise slip in the program is uncertain, but the delay may approach one year.

I would now like to turn to Dr. James E. Leiss, Chairman of the Process Evaluation Board, who will present the results of the PEB's evaluations and their recommendations. The charts that Dr. Leiss will use in his testimony before this Committee will be made available for the record. Following his presentation, we would be pleased to respond to any questions the Committee may have.

Mrs. **Bouquard**. Thank you.

Please proceed, Dr. Leiss.

Dr. **Leiss**. Thank you, Madam Chairman.

As you know, I have appeared before committees relating to the high energy nuclear physics program, so I am wearing a different hat here today in a job I didn't exactly offer to do, but I think it is a job that needed to be done.

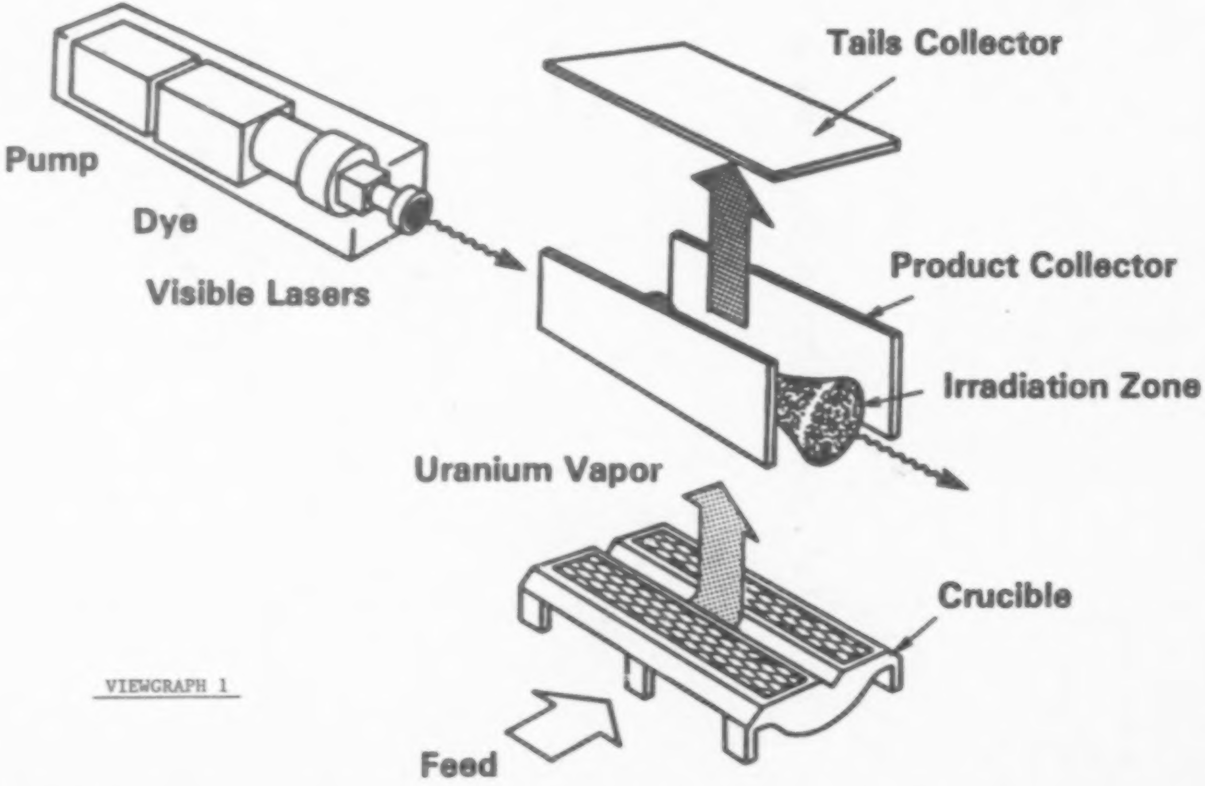
Before I start, I would like to comment that this has been an extremely intense review of the processes. We have had very excellent cooperation from the three proponents, each with their own process, obviously, hoping to win.

We have also had very excellent cooperation from the nuclear division of the Union Carbide Corp., which, in supporting our efforts, developed various economic and process models with the assistance of the laboratories so that they could analyze changes and sensitivities of individual parameters that were uncertain. They also developed what is called an MVSS, or multivariable sensitivity studies. In a statistical way, you could evaluate the impacts of many parameters on a process over a range of variable values. The ability to perform such evaluations is important because these uncertainties interact with each other in designing an optimum plant.

So, you can see the process we went through. I will be speaking of the MVSS studies as one of the important things that assisted us in understanding what uncertainty in different parameters meant.

What I would like to do in discussing our work is to very briefly give a description of each of the three processes, a little of the proponent plans, and cost estimates; what we consider are the probable cost of processes and uncertainties in each of these; how we scored the three processes, and finally the recommendations we made to Bill Voigt.

# Atomic Vapor Laser Isotope Separation Process

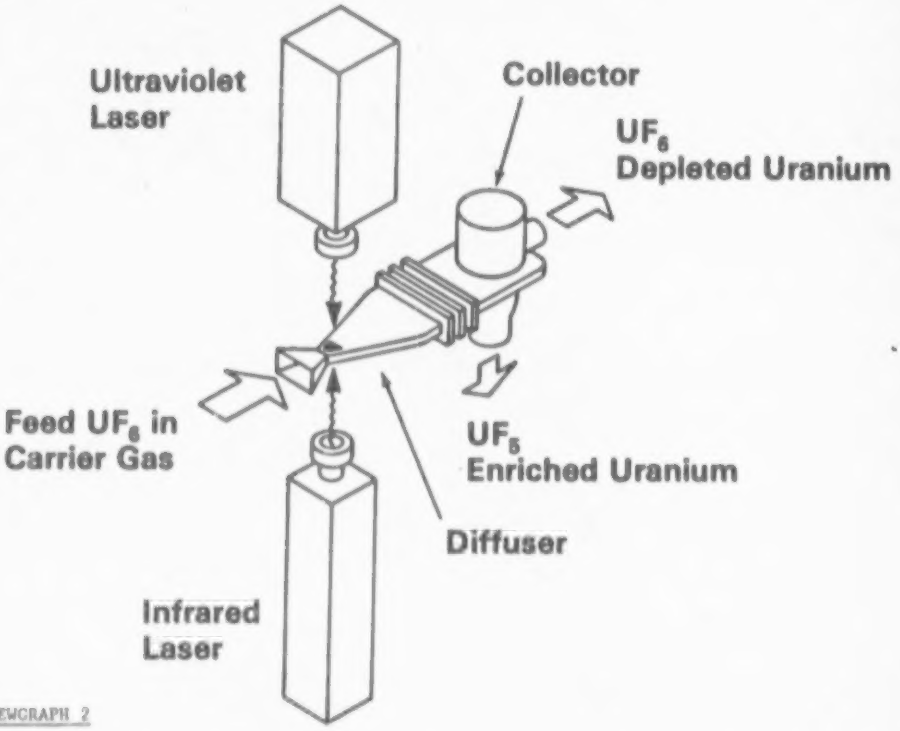

Pump
Dye
Visible Lasers
Tails Collector
Product Collector
Irradiation Zone
Uranium Vapor
Crucible
Feed

VIEWGRAPH 1

Viewgraph 1 shows schematically the atomic vapor laser isotope separation process. Briefly, at the bottom, uranium is vaporized with a low energy electron beam. This vapor then streams up into what is called a collector assembly, made of a coated graphite material. This vapor is then irradiated by a system of lasers that are tuned to the specific states in uranium-235, and with three different laser colors excite the uranium to the point where it ionizes.

These plates, so-called product collector plates, have a pulse of voltage put on them which pulls the ions of uranium-235 over to them. The neutral vapor, the uranium-238, then flows through to the so-called tails collector. This whole collector assembly operates above the melting point of uranium, and so the materials are collected as a liquid.

## Molecular Laser Isotope Separation Process



VIEWGRAPH 2

Viewgraph 2 depicts schematically the molecular laser isotope separation process. In this case, it uses $UF_6$, the same material used in the centrifuge or gaseous diffusion plants.

The carrier gas with a relatively small amount of $UF_6$ in it is pumped through supersonic nozzles which, in a very short period of time, cools the $UF_6$ vapor [deleted], so that as large a fraction as possible of the $UF_6$ is in what is called its molecular ground state. This gas is then irradiated with a combination of three different infrared lasers, the first of which selectively excites——

Mrs. **Bouquard**. The feed is $UF_6$?

Dr. **Leiss**. In a carrier gas.

Mrs. **Bouquard**. What is the feed in the AVLIS process?

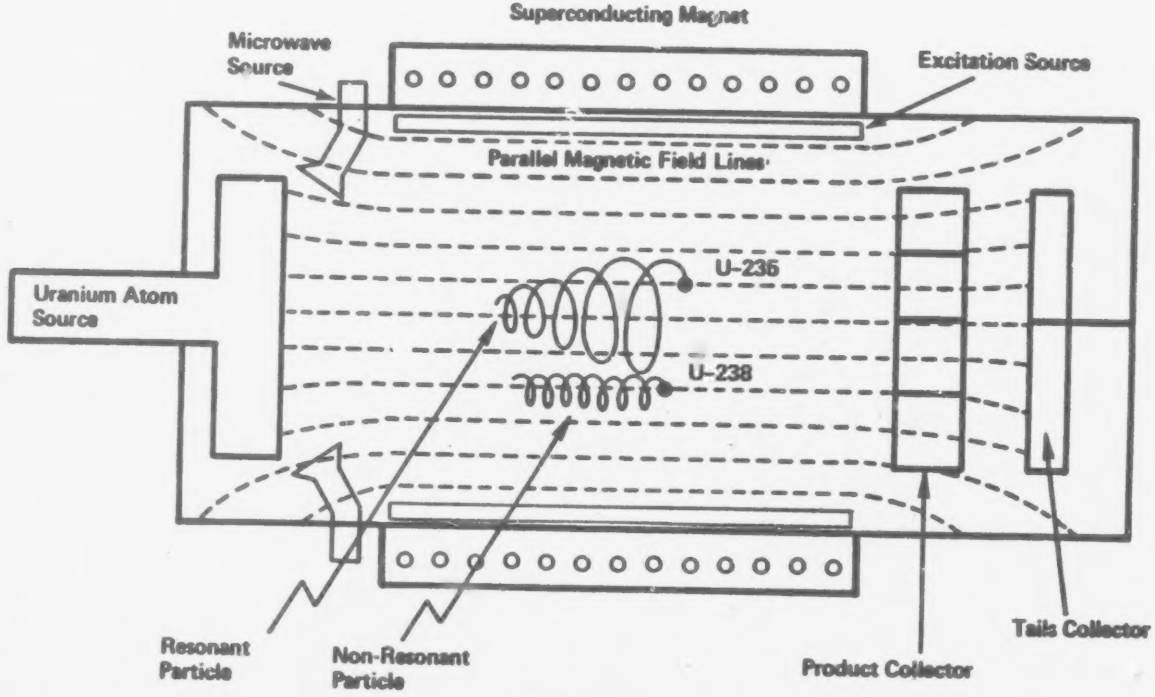
Dr. **Leiss**. In AVLIS, it is an atomic vapor. It is a gas, if you will, very diluted gas of uranium atoms that have been vaporized out of a metal.

Mrs. **Bouquard**. Thank you.

Mr. **Leiss**. In the MLIS process, this gas that has been supercooled is irradiated with three infrared and one ultraviolet laser, the first three of which excite vibrational states in the $UF_6$ molecules. The ultraviolet laser then carries these up to where one of the fluorine atoms have been knocked off the $UF_6$ to produce $UF_5$.

The $UF_5$ is a solid and is collected. One has to go through a cascade of stages to obtain the required enrichment. So the $UF_5$ is then refluorinated and run through additional steps in the process to get further enrichment.

# Plasma Separation Process
# Using Ion Cyclotron Resonance Principle


Superconducting Magnet
Microwave Source
Excitation Source
Parallel Magnetic Field Lines
Uranium Atom Source
U-235
U-238
Resonant Particle
Non-Resonant Particle
Product Collector
Tails Collector

VIEWGRAPH 3

Viewgraph 3 shows the plasma separation process, [PSP]. This is a plasma process. The assembly is in a large, superconducting magnetic field. Uranium atoms are sputtered—neutral uranium atoms are sputtered off the source plate on the left. Microwave radiation of very high frequency is then introduced, and is tuned to the electron cyclotron resonance in the plasma. These electrons are then excited to an energy such that they can ionize the sputtered uranium atoms.

These ions are confined by the magnetic field shown on the right. They enter a region where an oscillating electric field that is tuned to the ion cyclotron resonance of the uranium-235 ion, which imparts more energy to the uranium-235's than to the uranium-238's.

Using that extra energy results in larger orbit for the uranium-235 and one can then get selective collection on the product collector plates for the uranium-235 and, like the AVLIS process, the majority of the uranium-238's pass through to a tails collector.

With that brief description, I would like to go to Viewgraph 4, to gives you some information on the proponents' cost estimates.

**Proponent's Baseline Comparison**

| | AVLIS | MLIS | PSP |
|---|---|---|---|
| • RD&D Costs (FY 83-92), $ Millions (PEB Added Contingency) | 1,011 (50%) | 1,170 (60%) | 855 (40%) |
| • Plant Construction Costs, $ Millions | 920 | 1,960 | 1,510 |
| • Plant Power, MWe | 142 | 240 | 332 |
| • Plant Capacity, Millions of SWU | 9.22 | 8.89 | 8.76 |
| • Annual Operating Costs, $ Millions | 92 | 125 | 147 |

VIEWGRAPH 4

Very briefly, the first line gives the sum total of the research, development, and demonstration costs. This does not include the plant cost, but everything else for the period of fiscal year 1983 through 1992 based on the proponents' plans.

To this we have added a contingency which in our judgment would be wise for those processes.

The next lines, then, give the proposed cost of the separation plant. That would be a 9 million separation work unit per year plant for each case, the power required in megawatts per year, the plant capacity, and annual operating cost as claimed by each of the proponents for the three processes.

## Proponent's Baseline Comparison

| | | ($/SWU) | |
|---|---|---|---|
| | AVLIS | MLIS | PSP |
| • Plant Capital (25 Years + 10%) | 11.0 | 24.3 | 19.0 |
| • Operating | 10.0 | 14.1 | 16.8 |
| Subtotal | 21.0 | 38.4 | 35.8 |
| • Metal Conversion | 4.5 | 0 | 5.4 |
| Total, Equivalent | 25.5 | 38.4 | 41.2 |
| • RD&D Costs (Assumes RD&D Costs Amortized as Capital) | 12.1 | 14.5 | 10.8 |

VIEWGRAPH 5

Viewgraph 5 presents the proponents' cases for the enrichment costs for each of the processes. It is composed of three parts: The capital writeoff for the plant, approximately 11 percent per year assuming a 25-year writeoff of the plant capital cost; an increment for the operating cost; and, for the AVLIS and PSP processes an additional cost to account for the fact that the metal based processes, with the present industrial set-up we have for handling uranium, result in some additional costs. This is in recognition of the fact that the person who runs a power plant cares about uranium oxide fuel and what it costs. So, we tried to normalize the three processes in this manner.

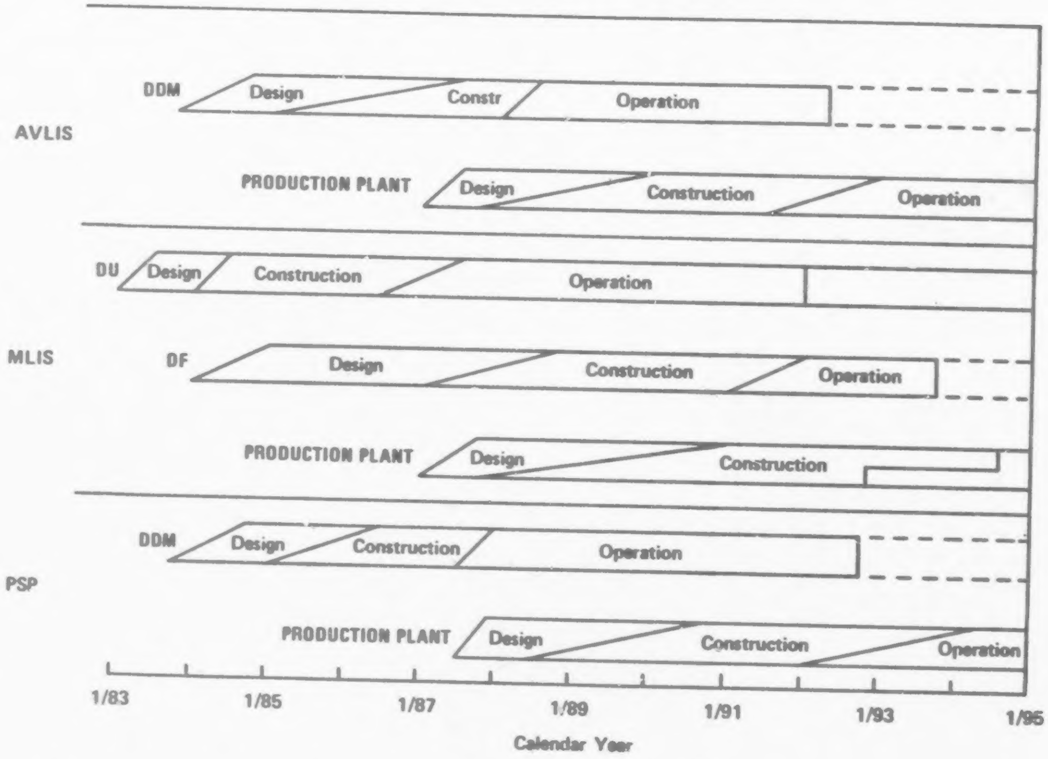
So from the proponents' cases. we get an equivalent SWU cost of $25.50 for AVLIS; $38.40 for MLIS process and $41.20 for PSP. We have also shown at the bottom what annual cost would have to be added, if you built one plant, to pay for the research and development program during this decade. In other words, we are projecting the total forward cost as an industry would have to do—what you would have to consider in an economic analysis.

Mrs. Bouquard. Where is the industry cost?

Dr. Leiss. It would be the sum for AVLIS of the $25.50, equivalent SWU cost, plus the 12.1, assuming you build only one plant. Of course, if you build more, you would write it off over more plants, but I think it is worth showing what those forward costs imply.

Mrs. Bouquard. Thank you.

# AIS Program Schedules



VIEWGRAPH 6

Dr. LEISS. Viewgraph 6 shows something about the schedules proposed by the three proponents. It is a little bit of a busy graph, but I will try to make a couple of points from it.

For AVLIS, they go through a development and demonstration module prior to building a production plant. This is one module of a large plant. The important point to note is that in this case they do have some operating experience on this development module before they have gone very far into the design of the production plant.

The same is true in the PSP process, shown at the bottom. In the MLIS process, the proponents chose not to propose a development module, but rather propose a development unit which would later be followed by a so-called development facility.

The development unit is a rather small unit. It would have only one supersonic nozzle, somewhat smaller than any of the nozzles in the production plant that is proposed. Yet, the development facility would not be operational until the construction of a production plant would be completed.

So, in the MLIS case, one would have to be prepared to make a commitment to a large, expensive plant based on only a relatively small amount of operational experience from the development unit.

Viewgraph 7 [deleted] shows several examples of estimates of the cost. The first is for the AVLIS process. The arrows at the bottom would show in one case, the base case, what the proponent of the AVLIS process proposed; the second, an optimized base case.

In this particular case, the AVLIS proponents had not used the UCC-ND codes to optimize their process. We had these code runs, so this optimized base case is somewhat lower than the proponent's proposal.

What we call PEB-2 is a case which we have developed where we have used the results of the peer review process and the agreements that were reached there. We have taken things which the proponents agreed were not included in their base design and from the various peer review discussions, we have taken and changed certain parameters to those values we consider the edge of credibility.

We have then had that particular case run. This is a case where we give the proponent essentially the maximum benefit of doubt on his case to give the best case for him, for his process. The curve [deleted] is the result of the MVSS analysis, where one allows the various uncertainties to vary statistically over a distribution, you run many cases and look at the distribution of costs that come out of this.

We think the MVSS codes contain most of the uncertainties that exist in this process.

You see, it is a relatively flat curve. The cost does go up, but what happens is that the enrichment improves in the process because various perturbing facts are now reduced.

We estimate that with the present design, AVLIS might have to back off on its density by a factor of two. Therefore, we conclude that even with that bound, it is still an attractive process, and we believe we have bounded the cost due to this uncertainty.

The next viewgraph [deleted] shows similar information for the MLIS process. Here the base case, $38.40 an SWU is shown and a

PEB case No. 2 is also shown. The base case has been optimized in this case to start with. The MVSS distribution is also shown. It is somewhat higher than either of these base cases, and I think that results because, for the various uncertainties, the proponents have chosen values that are on the optimistic side on essentially everything.

Therefore, when you put in statistical distributions, the distribution is going to sit above your base case.

## MLIS Principal Issues

- Firm Theoretical Model
- Infrared & Ultraviolet Cross Sections
- Stacked Nozzle Operation
- Small (Last) Stage Performance
- Laser Propagation (Including Small Density Changes)
- Raman Conversion Efficiency
- Laser Costs
- Laser Component Reliability & Lifetimes

VIEWGRAPH 10

Viewgraph 10, shows what we consider some of the uncertainties in the MLIS process. The first, the physics of a molecular process is very, very complex. It is very hard to get a good, fundamental model; one has to develop phenomenalogical models and then match them to various experimental data.

There are uncertainties in the absorption cross sections for ultraviolet and infrared. There are also uncertainties in the supersonic nozzles. Some of these lead to changes in the design of process plants for MLIS. Substantial numbers of changes were made very late in the evaluation process, so that they haven't had experimental confirmation, nor have they had an opportunity for full analysis.

There are questions related to laser propagation, also, that we have here. I don't have the time to go through all of these.

Now, some of these, we believe, are properly bounded by the MVSS analysis, but others are not. In particular, the question of whether small density changes would make it impossible to propagate the laser beam properly through the many stages of a process. If the laser beam cannot propagate, you have to essentially duplicate the lasers and put them in the back half of the process.

We really don't know how to bound these uncertainties properly. There is simply no peer agreement on whether there are troubles or not on these questions.

The third process, the PSP process, presents a very similar case. Again we show the base case, our PEB-2 case, and results of a MVSS distribution.

## PSP Principal Issues

* • Microwave Heating
* • $U^{++}$ Fraction
- Effects of Sputter/Reflection on Collection
* • Drive Field Uniformity
- Frame Blockage
- Sputtering Due to Unbaffled Tails
- Refurbishment Costs

*Radial Scaling Issues

VIEWGRAPH 11

In the PSP process, viewgraph 11, there are a number of uncertainties that could influence the costs. Those which we consider are most uncertain and serious are those related to radial scaling issues; that is, the preprototype superconducting magnet they have as an aperture of 60 cm. The process is planned for magnets with a 310-cm. aperture.

There are issues related to the microwave heating, defraction of doubly charged U-double-plus plasma, and particularly the uniformity of the drive field that is exciting these ions in the large diameter plasma which are particularly serious uncertainties.

I think probably all of these are bounded reasonably by the MVSS studies except the drive field uniformity and we simply don't know how to properly bound that uncertainty.

### Evaluation Grading

| | | AVLIS | MLIS | PSP |
|---|---|---|---|---|
| • Design of Plant and Development Module | (150) | 100 | 40 | 120 |
| • Process Performance and Scale-Up Risk | (600) | 400 | 150 | 250 |
| • Relative Economic Potential | (100) | 100 | 70 | 75 |
| • Program Management and Plans | (150) | 130 | 110 | 140 |
| Total | (1000) | 730 | 370 | 585 |

VIEWGRAPH 12

With that very brief description of the process and evaluations, viewgraph 12 shows the grading that we have given to the various categories in the formal evaluation process.

Overall, we give the AVLIS process a score of 730 points, the MLIS process a score of 370 points, and the PSP process a score of 585 points. This is our numerical scoring. I think viewgraph 13 in many ways gives a better overall evaluation of the three processes.

# Evaluation of Process & Plant Designs

| Process | Completeness of Plant Description | Changes During PEB Process | Overall Assessment | Prospects for <$40/SWU Process |
|---|---|---|---|---|
| AVLIS | Reasonable, But Lacking in Detail | Stable<br>• Reinsertion 1st Color<br>• Optimization Calls for Increased Standoff | Adequate; Principal Questions Are With Technical Performance,<br>DELETED | Reasonable if DELETED DELETED Performance Issues Resolved |
| PSP | Reasonably Detailed | Stable<br>• Source Changes<br>• Microwave Heating Design<br>• Drive Field Coil Design<br>• More Complete Physics Model | Adequate; Principal Questions Are With Performance Physics, Especially Those of Radial Scaling of Module | Marginal if Physics Issues Resolved Favorably. Probably Would Require Design Using Higher Magnetic Field |
| MLIS | Repeated Changes Make Plant Description Unclear | Radical Changes<br>• 3 Infrared Lasers<br>• New Nozzle Design<br>• Changed Optical Design<br>• Increased Rep Rate | Less Than Adequate; Many Physics and Technical Issues Which Could Have Large Cost Impact | Impossible to Determine at This Time. |

VIEWGRAPH 13

Here we evaluate, for each process, the completeness of the plant description, the amount of changes made during our PEB evaluation process, and our overall assessment. Finally, we give our judgment of the prospects for the process to produce SWV's at less than $40. We think the AVLIS process has a reasonably complete description of the plant, but does lack some detail. The designs have been relatively stable. There have been small changes made during our evaluation process. Our overall assessment of the process is that it is adequate. The principal questions are with technical performance, [deleted].

We think the prospect of $40 or less per SWU process is quite reasonable if the [deleted] [deleted] issues are resolved.

The plant description of PSP was reasonably detailed. It has been reasonably stable during the evaluation. There have been some changes, but we don't feel they have been too great. We think our overall assessment is that the process is adequate. The principal questions are with the performance physics, especially those related to radial scaling of the modules. We think the prospects of a less than $40 per SWU process are marginal even if these physics issues are resolved favorably. However, we believe it would require a design using a higher magnetic field with the magnets and other things that have been proposed which could improve the process.

The MLIS process has had repeated changes in the process design which make the description of the plant quite unclear. Some of these changes were rather radical. There has been an additional infrared laser introduced in the process. A completely new supersonic nozzle design was incorporated which has changed optics and the repetition rate of the lasers.

Our overall assessment is that the process is less than adequate. There are many physics and technical issues that could have a large cost impact, and we found it impossible to determine at this time whether a less than $40 process could result.

As a result of our evaluation, we have made a number of recommendations. We have recommended that DOE should select the AVLIS process for an engineering scale-up. [deleted.]

We have also recommended that funds for the development module should not be released by the DOE until the [deleted] issue is resolved. I would like to expound a little bit on that.

We believe that with a reoriented R&D program that they can come up with a [deleted] design that is acutally going to be the one they are going to use in a plant; that can be accomplished in a period of 18 to 24 months.

We feel rather strongly that the development module should be as much as possible a prototype of a plant, so you really know what it is you are evaluating and what product is going to cost.

We are also concerned, of course, that the budget process not add an extra year or two. So, our recommendation is that the DOE should not release the funds until they have resolved this issue but that the appropriation process should go forward.

We have also recommended that DOE should consider a limited R&D program on the PSP process, essentially exploiting what can be learned from the 1-meter superconducting magnet that they have now, which would provide a backup process.

We also have been very impressed at how much a really intense working peer review process contributes to evaluation in helping the processes themselves to face up to uncertainties in their process.

We are recommending that that be continued as a funded process. This is distinctly different than an advisory committee of experts that come in for a day or two and are smart and tell you what they can see. We are talking about a group that actually works and confronts the proponent with hard calculations from an adversary point of view.

## RECOMMENDED PLASMA SEPARATION PROCESS R&D PROGRAM

- DEMONSTRATE PROCESS PERFORMANCE WITH FULL APERTURE AND FULL DENSITY PLASMA IN THE PREPROTOTYPE MAGNET
- INVESTIGATE RESONANCE LINE WIDTH DEPENDENCE OF MAGNETIC FIELD
- DEVELOP AND DEMONSTRATE IMPROVED DRIVE COIL CONFIGURATIONS
- INVESTIGATE RADIAL SCALING OF DRIVE FIELD

VIEWGRAPH 14

Viewgraph 14 indicates that we are recommending an R&D program on the PSP process, and we have rather specific things that we think should be done on that.

First, they should demonstrate the performance using the full aperture possible with the 1-meter preprototype magnet. We believe they should carry out detailed investigations of the dependence of the resonance lined with the ions on the magnetic field, which wouldn't be able to get to the four Tesla field that they think might be desirable, but at least can see that the curve is truly pointing in the right direction.

We are quite convinced that better drive coils for spinning up the ions can be designed and I think they now agree that that is true, but they don't have new designs. We believe they could build and try new designs which could have a significant beneficial impact on thier economics. We also believe there are investigations that can be done that would help the understanding about the radial issues on the drive field.

We believe the success on the specific R&D program could greatly improve the PSP process as a backup technology to the AVLIS process. That ends the comments I have to make, Madam Chairman.

Mrs. **Bouquard**. Dr. Leiss, that was a very fine presentation.

At this time I would like to recongize Congressman Winn, who, as you know, is the ranking Republican member of the full Science and Technology Committee.

Congressman Winn.

Mr. **Winn**. Thank you, Madam Chairman.

I had an opening statement I would ask unanimous consent to have included in the record.

Mrs. **Bouquard**. Without objection, it will be.

Mr. **Winn**. Since we are running short of time, I think we ought to get on with the other witnesses.

[The opening statement of Mr. Winn follows:]

### Opening Statement of Hon. Larry Winn, Jr.

I want to thank you, Madam Chairman, for calling these hearings to reexamine the development of the advanced isotope separation process by DOE. The Committee has been watching this development since DOE aggressively began to pursue this technology in the middle of the last decade. At that time, DOE chose three competing processes: (1) the atomic vapor laser isotope separation process (AVLIS); (2) the molecular laser isotope separation process (MLIS); and (3) the plasma separation process (PSP). These three competing processes were developed by some of the most outstanding technological organizations within this country.

After its internal evaluation, DOE announced its intention to make a selection in the spring of this year, which it did with an announcement on April 30. However, two separate reviews of the program by the Energy Research Advisory Board concluded that such a selection should be made in the middle of 1983, after significantly refocusing the development programs. The ERAB panel stated. "There has not been sufficient progress to provide a firm scientific, technical or economic basis on which to select one of the three competing AIS processes for full-scale engineering development at this time." We hope to explore in these hearings why DOE came to its contrary conclusion.

The ERAB panel also stated that, ". . . should budgetary restraints or other factors force such a selection. . . ," and if a decision is made to develop the AVLIS process, the solid collector option (PSP) should be pursued in parallel to alleviate potential technical problems in AVLIS. DOE has followed this recommendation. However, the requested budget does not provide sufficient funds for this parallel development of the PSP process. We will be anxious to hear how DOE plans to fund this parallel development.

We are quite hopeful that the advanced isotope separation technology proves to be commercially successful. It provides the opportunity of not only significantly reducing the required energy use for uranium enrichment, but also significantly reducing the capital requirements for building uranium enrichment plants. It would also represent a more efficient use of our uranium resources. This could give the United States a tremendous competitive advantage in the international uranium enrichment market.

I would also like to welcome the representative from the DOE defense programs, Assistant Secretary Herman Roser. He will be testifying concerning the weapons production application of this technology. This is an area in which we are all concerned, during this increased attention to our nation's defense needs.

Thank you once again, Madam Chairman. I look forward to hearing from our distinguished witnesses today.

Mrs. **Bouquard**. We are happy to have you with us, Congressman Hollenbeck, Congressman Young, and Congressman Volkmer.

Do any of you gentlemen have questions?

Mr. **Volkmer**. Not now, Madam Chairman, but later.

Mrs. **Bouquard**. Mr. Roser, please proceed.

## STATEMENT OF HERMAN E. ROSER, U.S. ASSISTANT SECRETARY FOR DEFENSE PROGRAMS, DEPARTMENT OF ENERGY

Mr. Roser. Madam Chairman and members of the committee, thank you for inviting me to testify about the plutonium special isotope separation program. I understand that the primary purpose of this hearing is to review the uranium advanced isotope separation program budget request, but that you are also interested in the classified activities of the plutonium SIS program. [Deleted.]

First, as a matter of background, I would like to call your attention to the goals of the SIS program and the driving force for achieving these goals.

## DEFENSE PROGRAMS – NUCLEAR MATERIALS

### SPECIAL ISOTOPE SEPARATION

### GOALS

- PHASE 1 (CURRENT PROGRAM)
  - DEVELOP TECHNOLOGY
  - BUILD PLANT BY 1989 TO CLEAN UP DELETED FUEL GRADE PLUTONIUM TO WEAPON GRADE
- PHASE 2

  DEVELOP TECHNOLOGY AND EXPAND PHASE 1 PLANT, BY FY 1991 TO:
  - CLEAN UP DELETED WEAPON-GRADE PLUTONIUM TO REDUCE RADIATION EXPOSURES
  - SEPARATE DELETED PU ISOTOPES FOR WEAPON RESEARCH AND DEVELOPMENT

CHART I

The goals of the SIS program are stated on chart I. A plutonium SIS production plant would provide the defense programs effort with major new technical capabilities for meeting our requirements for weapon-grade plutonium and other needs.

More specifically, this plant could increase the supply of weapon grade plutonium by enriching nonweapon grade plutonium which is available from existing Government inventories.

An SIS plant could also clean up the existing weapon grade plutonium stockpile by the removal of undesirable plutonium isotopes; for example, $Pu^{238}$, $Pu^{240}$, and $Pu^{241}$, which are the major sources of radiation emanating from plutonium. This would reduce the radiation exposure to the Department of Energy defense programs and DOE contractor personnel who manufacture or handle nuclear weapons and to the Department of Defense pesonnel who deploy these weapons.

In addition, and SIS production plant would be a more cost-effective method for obtaining the less fissile isotopes of plutonium, such as $Pu^{240}$ and $Pu^{242}$. [Deleted.]

# DEFENSE PROGRAMS — NUCLEAR MATERIALS

## SPECIAL ISOTOPE SEPARATION

| PROCESS | PERFORMER | FUNDING ($ MILLIONS) PRIOR YEARS | FY 1982 | FY 1983 PRES. BUD. |
|---|---|---|---|---|
| ATOMIC VAPOR LASER ISOTOPE SEPARATION PROCESS | LIVERMORE | $24.5 | $18.1 | ($24.3/$5.0) |
| ADVANCED ISOTOPE SEPARATION FACILITY | LIVERMORE | $ 3.8 | $14.0 | $7.2 |
| MOLECULAR LASER ISOTOPE SEPARATION PROCESS | LOS ALAMOS | $ 7.7 | $12.0 | ($24.3/$5.0) |
| PLASMA SEPARATION PROCESS | TRW/LOS ALAMOS | 0 | $ 0.3 | (–/$5.0) |
| NUCLEAR MATERIALS HANDLING SUPPORT PRODUCTION PLANT DESIGN/CONSTRUCTION | SAVANNAH RIVER PLANT/DU PONT | $ 0.9 | $ 1.5 | $2.5 |
| MISCELLANEOUS | – | $ 1.3 | $ 0.7 | $1.0 |
| TOTAL SIS PROGRAM | | $38.2 | $46.6 | $40.0 |

CHART II

As shown in chart II, three plutonium SIS processes are being considered: The Lawrence Livermore National Laboratory atomic vapor laser isotope separation process; the Los Alamos National Laboratory molecular laser isotope separation process; and the TRW plasma separation process.

[Deleted.]

In the SIS program, we hope to select a primary process and a backup process early in fiscal year 1983. Of course, our ability to make this selection will depend heavily on achieving planned technical milestones.

[Deleted.]

In fiscal year 1983, after process selection, the bulk of the funding will go to the selected process and a lesser amount to the backup process. We consider AVLIS and MLIS to be the leading contenders for the primary process selection and, subsequently, the nonselected process and PSP as the contenders for the backup process selection.

## DEFENSE PROGRAMS — NUCLEAR MATERIALS

---

## SPECIAL ISOTOPE SEPARATION PROGRAM MILESTONES — CURRENT PROGRAM

| | |
|---|---|
| DELETED | |
| **PRIMARY PROCESS SELECTION** | **1983** |
| DELETED | |
| **PRODUCTION PLANT OPERATIONAL** | **1989** |

CHART III

Chart III shows the key milestones for the current SIS program. [Deleted.]

The fiscal year 1983 request of $40 million, with appropriate outyear funding, will allow competion of construction of an SIS production plant in fiscal year 1989.

[Deleted.]

[Deleted.] These requirements, and the production capability to meet them, are shown graphically in chart IV. [Deleted.]

We have an adequate supply of DOE-owned nonweapon grade plutonium to provide feed for [deleted] operation of an SIS production facility. This is shown in chart V. [Deleted.]

With regard to your interest in how scarce resources can be best used to maximize the benefit to both programs, I would like to reiterate the need for orderly completion of the SIS technology research development and demonstration followed as closely as practical by construction of a plutonium isotope separation production facility.

We need this capability on line as soon as feasible. [Deleted.] To this end, we are striving to achieve our plutonium isotope separation program goals within our limited fiscal resources.

As I indicated earlier, we hope to make the SIS production selection early in fiscal year 1983. This selection is predicated on successfully achieving program milestones during fiscal year 1982. [Deleted.]

In summary, the expeditious development of one of the SIS techniques, supported by a backup process, will help to provide maximum assurance of success while minimizing the utilization of scarce resources in meeting the requirements for weapons materials.

Madam Chairman, that ends my prepared statement. I will now answer any questions you may have.

Mrs. BOUQUARD. Thank you very much, Mr. Roser.

[The statement of Mr. Roser follows:]

*DELETED*

TESTIMONY OF HERMAN E. ROSER
ASSISTANT SECRETARY FOR DEFENSE PROGRAMS
TO
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
OF
HOUSE SCIENCE AND TECHNOLOGY COMMITTEE

Madam Chairman and members of the committee, thank you for inviting me to testify about the plutonium Special Isotope Separation (SIS) program. I understand that the primary purpose of this hearing is to review the uranium Advanced Isotope Separation (AIS) program budget request, but that you are also interested in the classified activities of the plutonium SIS program *DELETED*

First, as a matter of background, I would like to call your attention to the goals of the SIS program and the driving force for achieving those goals.

The goals of the SIS program are stated on Chart 1. A plutonium SIS production plant would provide the Defense Programs (DP) effort with major new technical capabilities for meeting our requirements for weapon-grade plutonium and other needs. More specifically, this plant could increase the supply of weapon-grade plutonium by enriching nonweapon-grade plutonium which is available from existing Government inventories. An SIS plant could also "clean up" the existing weapon-grade plutonium stockpile by the removal of undesirable plutonium isotopes; e.g., Pu-238, Pu-240, and Pu-241, which are the major sources of radiation emanating from plutonium. This would reduce the radiation exposure to the Department of Energy (DOE) DP and DOE contractor personnel who manufacture or handle nuclear weapons and to the Department of Defense (DOD) personnel who deploy these weapons.

In addition, an SIS production plant would be a more cost-effective method for obtaining the less fissile isotopes of plutonium, such as Pu-240 and Pu-242.

*DELETED*

As shown in the next chart (Chart 2), three plutonium SIS processes are being considered: (1) the Lawrence Livermore National Laboratory (LLNL) Atomic Vapor Laser Isotope Separation (AVLIS) process; (2) the Los Alamos National Laboratory (LANL) Molecular Laser Isotope Separation (MLIS) process; and (3) the TRW Plasma Separation Process (PSP). As you know, the same processes have been under development for the uranium program at the same sites, *DELETED* *DELETED*

In the SIS program, we hope to select a primary process and a backup process early in FY 1983. Of course, our ability to make this selection will depend heavily on achieving planned technical milestones.

*DELETED*

In FY 1983, after process selection, the bulk of the funding will go to the selected process and a lesser amount to the backup process. We consider AVLIS and MLIS to be the leading contenders for the primary process selection and, subsequently, the nonselected process and PSP as the contenders for the backup process selection. *DELETED*

*DELETED*

This next chart (Chart 3) shows the key milestones for the current SIS program.

*DELETED* The FY 1983 request of $40 million, with appropriate outyear funding, would allow completion of construction of an SIS production plant in FY 1989.

*DELETED*

We have an adequate supply of DOE-owned nonweapon-grade plutonium to provide feed for *DELETED* operation of an SIS production facility. This is shown in my next chart *DELETED*

With regard to your interest in how scarce resources can be best used to maximize the benefit to both programs, I would like to reiterate the need for orderly completion of the SIS technology research development and demonstration followed as closely as practical by construction of a plutonium isotope separation production capability.

*DELETED* To this end, we are striving to achieve our plutonium isotope separation program goals within our limited fiscal resources.

As I indicated earlier, we hope to make the SIS process selection early in FY 1983. This selection is predicated on successfully achieving program milestones during FY 1982.

*DELETED*

In summary, the expeditious development of one of the SIS techniques, supported by a backup process, will help to provide maximum assurance of success, while minimizing the utilization of scarce resources in meeting the requirements for weapons materials.

Madam Chairman, that ends my prepared statement. I will now answer any questions you may have.

*DELETED*

# DEFENSE PROGRAMS — NUCLEAR MATERIALS

## SPECIAL ISOTOPE SEPARATION

## GOALS

- PHASE 1 (CURRENT PROGRAM)
  - DEVELOP TECHNOLOGY
  - BUILD PLANT BY 1989 TO CLEAN UP DELETED FUEL GRADE PLUTONIUM TO WEAPON GRADE
- PHASE 2

  DEVELOP TECHNOLOGY AND EXPAND PHASE 1 PLANT, BY FY 1991 TO:
  - CLEAN UP DELETED WEAPON-GRADE PLUTONIUM TO REDUCE RADIATION EXPOSURES
  - SEPARATE DELETED PU ISOTOPES FOR WEAPON RESEARCH AND DEVELOPMENT

Chart 1

# DEFENSE PROGRAMS — NUCLEAR MATERIALS

## SPECIAL ISOTOPE SEPARATION

| | | FUNDING ($ MILLIONS) | | |
|---|---|---|---|---|
| PROCESS | PERFORMER | PRIOR YEARS | FY 1982 | FY 1983 PRES. BUD. |
| ATOMIC VAPOR LASER ISOTOPE SEPARATION PROCESS | LIVERMORE | $24.5 | $18.1 | ($24.3/$5.0) |
| ADVANCED ISOTOPE SEPARATION FACILITY | LIVERMORE | $ 3.8 | $14.0 | $7.2 |
| MOLECULAR LASER ISOTOPE SEPARATION PROCESS | LOS ALAMOS | $ 7.7 | $12.0 | ($24.3/$5.0) |
| PLASMA SEPARATION PROCESS | TRW/LOS ALAMOS | 0 | $ 0.3 | (–/$5.0) |
| NUCLEAR MATERIALS HANDLING SUPPORT PRODUCTION PLANT DESIGN/CONSTRUCTION | SAVANNAH RIVER PLANT/DU PONT | $ 0.9 | $ 1.5 | $2.5 |
| MISCELLANEOUS | – | $ 1.3 | $ 0.7 | $1.0 |
| TOTAL SIS PROGRAM | | $38.2 | $46.6 | $40.0 |

Chart 2

## DEFENSE PROGRAMS — NUCLEAR MATERIALS

---

## SPECIAL ISOTOPE SEPARATION PROGRAM MILESTONES — CURRENT PROGRAM

| | |
|---|---|
| DELETED | |
| **PRIMARY PROCESS SELECTION** | **1983** |
| DELETED | |
| **PRODUCTION PLANT OPERATIONAL** | **1989** |

Chart 3

Mrs. Bouquard. Mr. Voigt, we were surprised to learn today that there is going to be a year's delay in the startup of the demonstration module [Deleted.]

Would you explain this issue and how it affects the design module to such an extent that we can expect a year's slippage?

Mr. Voigt. Well, based on the recommendations of the Process Evaluation Board, and looking at some of the technical uncertainties associated with that process, it was determined from a programmatic standpoint it would not be prudent to go ahead with the detailed design of the development module, and hence the follow-or plants as well, until we had better defined what that plant really looked like.

[Deleted.] That is the basis by which we are currently looking at our 1984 budget formulation and are assessing whether we should or should not proceed with the development module within the framework of that budget.

Mrs. Bouquard. You state that the Process Evaluation Board estimated that it could take 18 to 24 months to obtain an answer [deleted]. If we put more money into this problem, more resources, could we get an answer sooner, or is this a technical problem that is going to take 1½ or 2 years to solve regardless of the money? Is it a financial problem or a technical problem?

Dr. Leiss. They may be somewhat resource limited in the speed with which they can answer this, but I believe it is going to take a good fraction of that time to come up with their answers.

They do have various possibilities for shortening the time. One is to carry out sufficient demonstrations that they can prove that their peers are wrong, that it will work.

[Deleted.]

We believe that there are solutions. We believe that it is very important that the solution you choose to put in a demonstration module is the one that you are going to use in the production plant so you don't start building a production plant with a cloud of uncertainty on what you are going to use.

Mrs. Bouquard. How much is a year's slippage in the program going to cost over the life of the AIS program?

Dr. Leiss. I think if you discount inflation, it is probably about 1 year's operating budget, which is $30 to $40 million.

Mrs. Bouquard. Bill, it has been about a month since the Department announced the selection of the AVLIS process for large-scale development demonstration, as well as decision to continue with the PSP process. Will you tell us why we don't have a detailed program for 1983 at this time?

Mr. Voigt. Well, we do have a program as originally defined by Livermore before we went into the evaluation process, but as a result of some of the recommendations of the Process Evaluation Board, we have asked them to redevelop the plan within a framework of trying to address the key technical uncertainty. I am scheduled to meet with the Livermore management Tuesday of next week to discuss the details of their program plan.

Mrs. Bouquard. Do you expect to remain within the $34.2 million originally requested, or do you expect to ask for other money from other parts of the enrichment program? If so, what parts of the program?

Mr. VOIGT. The $34 million 1983 budget authority that was identified in one of my earlier charts assumed that we would only be carrying forth one process. That, in my judgment right now, is sufficient to carry the AVLIS process forward within the framework of the program plan that we presently identified. It is not sufficient to carry forth the plasma separation program.

We are currently evaluating the need for a supplemental budget.

Mrs. BOUQUARD. Can we expect a detailed program for fiscal year 1983?

Mr. VOIGT. Yes. Madam Chairman, that would be in the event we do submit a supplemental, that would be part of the supplemental in terms of the delineation of the program.

Mrs. BOUQUARD. If you do have to seek additional fundings, from what part of the enrichment program do you expect tc look for additional funding?

Mr. VOIGT. That would be over and above any of the existing dollars we have in the program.

Mrs. BOUQUARD. As members of the committee know, our rules recognize and the chair recognizes members for questioning in the order they arrived at today's hearing. At this time I would like to recognize Congressman Lujan.

Mr. LUJAN. Thank you, Madam Chairman.

We have been discussing the decision and why the decision was made.

Have any of processes produced any enriched uranium?

Mr. VOIGT. I think it is fair to say, Mr. Lujan, that we have produced gram quantities from all three processes.

Mr. LUJAN. [Deleted.]

The enriched uranium would rise and the tails then would proceed on. In the vapor process you are reoving the tails. What is left is the enriched uranium. So that you are moving a lot more material. In other words, what you are really doing in one case is separating the enriched uranium, which is much less, and in the other you are removing the tails.

That would pose a problem, at least in my mind, that you did not pick up all the tails, so that you would perhaps have to have a reprocessing of the tails that are left, besides moving a lot more material.

Dr. LEISS. Perhaps I can try to answer that, Congressman. In all of the processes the primary product that you pull out of the mainstream is the $U^{235}$, as much as possible. I don't think they are different in that. In all the processes you must move a lot of material, either as a gas with the uranium hexafluoride added to it, or as some form of an atomic or neutral vapor.

Mr. LUJAN. Yes, my understanding is that in the gas process you are removing the undesirable material, that is the material which you do not want to keep?

Dr. LEISS. I don't believe, sir, that is a very good analogy. In each case you are removing the material you want, which is enriched uranium.

There is a tail stream that has uranium-238 in it and a certain amount of $U^{235}$. When you have pulled the tails down to the economic optimum level, then you stop. But I think I should emphasize that if one starts looking at detailed questions such as you are asking, that isn't really the right thing to ask. The right thing to realize is that the primary purpose is economics. How to get a less expensive, higher productivity enrichment process. So, you have to look at the total cost of the process in asking the questions.

Mr. LUJAN. Your chart seemed a little different because under the atomic vapor laser isotope separation process it shows the tails collector being up here, that it is going to rise with the vapor, the tails are going to rise with the vapor, and the enriched uranium, or the product, is what is going to come out the end.

So that, well, you understand what I mean but you are not agreeing with me.

Dr. LEISS. That is correct, sir.

Dr. HABERMAN. But the chart does not show all the stages in the process.

Mr. LUJAN. That is close enough.

On the scale-up, you assign 60 percent of the value as to who would be selected based on which would be the most probable for scale-up. From what I gather, the primary difficulty with the scale-up of MLIS is the question of nozzles—that the nozzles could not be scaled up. So obviously, to my way of thinking, at least, you assigned 60 percent of the value to the fact that you couldn't scale up that nozzle.

Dr. LEISS. No, sir, that is really not a correct perception. We assigned 60 percent of the score to an assessment of the technical and economic risks involved in the process. There are real uncertainties related to the nozzle, and its performance, because it is something very new, and there is essentially zero experience in a nozzle in this particular use and configuration.

But that is only one of a number of uncertainties.

Mr. LUJAN. Was that the biggest uncertainty?

Dr. LEISS. No, sir.

Mr. LUJAN. What?

Dr. LEISS. It would take longer than I think you want to spend to go into details on the thing, but there are a number of uncertainties. Certainly the nozzle and how the nozzle performs in terms of pressure recovery, which has to do with how much it takes to separate the uranium isotpes, how well the density of the gas behaves, and it has to behave extremely well in great detail or the lasers won't propagate properly. Then you will have to reproduce lasers and reintroduce their beams into the process chamber, and determine how well the lasers themselves will operate, and what their cost and reliability will be. All of these are uncertainties.

I think one would have to go through the list in great detail to answer all the questions, but the nozzle is only one part of the analysis. It is an uncertain area, but certainly not the dominant question.

Mr. LUJAN. Let me bring that all together to one point and why I was raising those questions.

In abandoning MLIS, it seems to me that you are abandoning something that has had some good successes. As a matter of fact, part of the reason for throwing it out was that there were too many changes there toward the end.

Dr. LEISS. No. Part of the reason for the large uncertainty in cost is the fact that we don't know how to bound the cost, the upper limit of the cost, because of the many changes.

Mr. LUJAN. So that the advances really did prove detrimental to the selecting of that process because some advances came late in the game as that evaluation was going on, and you couldn't evaluate them, so that they did work to the disadvantage.

Dr. LEISS. Sir, it is a chicken and egg problem. The MLIS process and conceptual plant design they put together had serious problems because the physics that they had been able to demonstrate did not satisfy the basis on which the plant was designed. They had to make changes to get within the physics.

So, I understand the changes they made, they had to do it, but that did throw in major uncertainties. If you discount all of those, it is our judgment that the cost of the MLIS processing is going to be more expensive certainly then the AVLIS process and probably more expensive than the PSP process.

Mr. LUJAN. All right. And because of these uncertainties that you talk about, wouldn't it be prudent to conduct a small experimental physics program, to put in a little money to be doing some of that? [Deleted.]

Dr. LEISS. [Deleted.] I think within the resources that appear to be available, it would be my judgment that it ought to be used on those that have the greatest promise, not on those that don't.

[Deleted.]

Mr. ROSER. [Deleted.]

But we do intend to continue the research program on the MLIS process for the SIS, as well as a small effort on PSP.

Mr. LUJAN. Would you say that again?

Mr. ROSER. We do intend to continue the MLIS process as a candidate for the SIS production plant, as well as some modest efforts on the PSP process.

[Deleted.]

Mr. LUJAN. I am concerned that we have done this research—and I don't mean to be taking so much time, I will quit right after this one—that we have done all these experiments, and then we went through a selection process.

Now we are saying, well, OK, we picked this one. So all of this that has gone on, including spending $30 million a year for a total of $300 million, that we are just going to take it and throw it out. It seems prudent to continue some of the things that might eventually be beneficial.

[Deleted.]

Thank you, Madam Chairman.

Mrs. BOUQUARD. Thank you, Mr. Lujan.

Mr. Volkmer.

Mr. VOLKMER. Thank you, Madam Chairman. I would like to go back to the discussion just to clarify so I understand it.

On the problems with regard to the AVLIS system [deleted]. I understand it is a question of design, is that it?

Dr. LEISS. That is part of it.

Mr. VOLKMER. What is the probability of this being something that is not going to be able to be corrected as far as being able to use the AVLIS system?

Dr. LEISS. I think the probability of a satisfactory solution [deleted] on AVLIS is very high.

Mr. **Volkmer**. Is there a possibility that there will be no solution?

Dr. **Leiss**. At this state of development of processes, I think one has to recognize that there is always some possibility.

Mr. **Volkmer**. Possibility, but you would say that would be remote?

Dr. **Leiss**. I think that our analysis would indicate, when you consider that there are other options, [deleted] that the probability of a solution that is reasonably attractive economically is very high.

Mr. **Volkmer**. With that solution, you are sure that the AVLIS system would still be the best system?

Dr. **Leiss**. I believe that would be our judgment. Well, it was our judgment in our report, sir.

Mr. **Volkmer**. No matter what [deleted] is used, then?

Dr. **Leiss**. Yes, sir.

Mr. **Volkmer**. I have no further questions.

Mrs. **Bouquard**. Thank you very much, Mr. Volkmer.

I have two more issues that I would like to get into. [Deleted.]

Mr. **Voigt**. It is our plan to cite the development module adjacent to the K-25 plant at Oak Ridge.

Mrs. **Bouquard**. I think that is a very good location. I will agree with that.

Mr. Roser, you said that the SIS process selection will take place in early 1983. Are you planning on using a process evaluation board similar to that employed to select the AIS lead technology? How do you plan to make that selection?

Mr. **Roser**. We intend to follow much the same process. We believe very strongly in the peer review process that was mentioned by Dr. Leiss. We think that is an excellent way to go, and we are currently developing a plan which will be very similar for the selection of the final SIS process that was used in arriving at the AIS process.

I think we have the luxury of not having to do it quite as rapidly because our final goal is perhaps a little different than the final goal of the AIS process, which is to produce separative work units at the least possible cost. We have to be concerned not only about cost, but about location of facilities, and so forth.

Basically, we will try to select the least costly technology, but we are more concerned with selecting the best technology to get the job done because the product is one that is used in the national security program, rather than one that competes in the marketplace for the production of electricity.

Mrs. **Bouquard**. Thank you very much.

Mr. Lujan.

Mr. **Lujan**. Thank you, Madam Chairman.

That means, then, Herman, that MLIS will get no funding from the energy portion, and that you are going to have to increase the funding out of the defense pocket for SIS?

Mr. **Roser**. Actually, we are funding the SIS process in fiscal year 1983 at a little higher level than we had in the past in any event. The AVLIS process is being funded a little more heavily. Both are being funded a little more heavily, and we are pursuing the PSP process at Los Alamos.

I thought that would make you feel good. We do that in the "Land of Enchantment" and the land of high technology, the great State of New Mexico. I would like to get that pitch in, since Bill got the Tennessee pitch in.

But in answer to your question, Congressman, yes, we will be putting a little more funding in the SIS process in fiscal year 1983 because of the reduction of funding that will be put in by the AVLIS people, but we will still be at a low level until a final selection is made on the primary technology and a selection is made of which of the two backup technologies will be pursued.

In any event, some of them will be pursued at Los Alamos.

[Deleted.]

Mr. LUJAN. Bill, you said that at some point down the line we will have to make a determination between advanced centrifuge technology and AIS technology. We are going to go through another selection process for that at some point in the future?

Mr. VOIGT. Well, I don't see it as a selection process as such, within the structured process, evaluation board, source selection official, but mainly within the framework of looking at the totality of demand against the system, and how we meet that demand. Do we do it with the three diffusion plants, plus GCEP, or do we shut down some of the more power intensive diffusion plants and displace them with more advanced technology, or even new enrichment capacity, depending on what the demand is?

That is something we study every year, Congressman Lujan, in the framework of what is the best way to operate the enrichment enterprise in total.

If I might just add one point which may be of interest to the chairman, as well as to the other committee members, to toot our own horn a little bit, Madam Chairman, I am pleased to state that we have signed four contracts with Egypt, three new contracts for reactors ranging from 900 to 1,000 megawatts and one upgraded contract from 660 to 900.

This represents over its 30-year life revenues to the Government in current year dollars of $1.5 billion. So, it was a real step forward in our marketing program.

Mrs. BOUQUARD. I certainly want to commend you for that. I think we have all seen the results of an inconsistent energy program and what it has done on our marketing.

Where do the AVLIS and PSP technologies stand in relation to our gas centrifuge technology, knowing we do have technical uncertainties surrounding the advanced isotope separation technologies? Can we really expect it to be fully deployed in the nineties or are we really going to see this available after the turn of the century?

Mr. VOIGT. In terms of relation to the gas centrifuge program, of course, we have been working on gas centrifuges for about 20 years now. The technology is well in hand. We have gone through extensive testing.

With respect to the gas centrifuge program, the first objective of course was to achieve a 50-percent increase in performance through what we call our SET IV machine. We have already achieved a greater than 25-percent share of that 50 percent. So, we are optimistic about it.

With regard to the SET V and SET VI, we are still in the process of defining what that program really consists of. It could be somewhat of a departure from existing technology, but in terms of the machine itself I do not expect that. So, hence we are very high on the learning curve vis-a-vis technology.

I wish I could say the same on the advanced isotope separation, but I am hopeful through the building of an advanced module and scaling up of equipment, then we would be in a better position of judging whether that technology can be put to production, but I do not think that decision can be made until the early nineties.

Mrs. **BOUQUARD**. So we really can't expect it to be fully deployed in the 1990's?

Mr. **VOIGT**. That is my current estimate, yes.

Mrs. **BOUQUARD**. Thank you very much.

Mr. **LUJAN**. I have one unrelated question, also.

We are dealing with it in another area. In the Nuclear Regulatory Commission authorization we are looking at hopefully limiting imports to 20-percent uranium.

How does that fit into the enrichment process? Does it limit you? I wouldn't want you to take a position unless the position was going to be that yes, that is a good idea.

Mr. **VOIGT**. Then you don't want my position, sir.

Mr. **LUJAN**. All right.

Mrs. **BOUQUARD**. Again, thank you for being our witnesses today. We appreciate your testimony.

The next scheduled hearing for the subcommittee will be on June 2 at 1:30 in room 2318. They are going to be very important hearings. The subject will be our national laboratories' personnel concerns. This will be a joint hearing with the Energy Development and Application Subcommittee.

Thank you very much. The subcommittee is now adjourned.

[Whereupon, at 11:05 a.m. the subcommittee adjourned.]

[App. IV, questions and answers submitted for the record, and app. V, additional material submitted for the record, follow:]

# APPENDIX IV

## QUESTIONS AND ANSWERS SUBMITTED FOR THE RECORD

DON FUQUA, FLA., CHAIRMAN

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD BOUQUARD, TENN.
JAMES J. BLANCHARD, MICH.
DOUG WALGREN, PA.
RONNIE G. FLIPPO, ALA.
DAN GLICKMAN, KANS.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
RICHARD C. WHITE, TEX.
HAROLD L. VOLKMER, MO.
HOWARD WOLPE, MICH.
BILL NELSON, FLA.
STANLEY N. LUNDINE, N.Y.
ALLEN E. ERTEL, PA.
BOB SHAMANSKY, OHIO
RALPH M. HALL, TEX.
DAVE MC CURDY, OKLA.
MERVYN M. DYMALLY, CALIF.

LARRY WINN, JR., KANS.
BARRY M. GOLDWATER, JR., CALIF.
HAMILTON FISH, JR., N.Y.
MANUEL LUJAN, JR., N. MEX.
HAROLD C. HOLLENBECK, N.J.
ROBERT S. WALKER, PA.
EDWIN B. FORSYTHE, N.J.
WILLIAM CARNEY, N.Y.
MARGARET M. HECKLER, MASS.
F. JAMES SENSENBRENNER, WIS.
VIN WEBER, MINN.
JUDD GREGG, N.H.
RAYMOND J. MC GRATH, N.Y.
JOE SKEEN, N. MEX.
CLAUDINE SCHNEIDER, R.I.
JIM DUNN, MICH.
BILL LOWERY, CALIF.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

HAROLD P. HANSON
EXECUTIVE DIRECTOR

ROBERT C. KETCHAM
REGINA A. DAVIS
MARTHA KREBS
GEORGE S. KOPP
JOHN V. DUGAN, JR.
THOMAS H. MOSS
DARRELL R. BRANSCOME
ANTHONY C. TAYLOR
ROBERT B. NICHOLAS

GERALD E. JENKS
MINORITY STAFF DIRECTOR

June 7, 1982

Dr. Shelby T. Brewer
Asst. Secty. for Nuclear Energy
U.S. Department of Energy
Washington, DC 20585

Dear Shelby:

We appreciated having Mr. Voigt, Dr. Haberman, and Dr. Leiss testify on the Department of Energy's Advanced Isotope Separation program at the Subcommittee's FY 1983 budget review hearing on May 20, 1982. Chairman Bouquard would like to supplement the record of the hearing with some additional questions she has regarding the program. We request that your replies be prepared in both a classified version, where appropriate, and in an unclassified version which can be made a part of the public record. We appreciate your cooperation on this matter and we hope that this information can be provided by June 21, 1982.

If you have any general questions regarding this request, please contact me at 225-8056. If you have any questions regarding the specifics, please contact Dr. Harlan Watson of the Subcommittee staff at 225-3472.

Sincerely,

Jack

JOHN V. DUGAN, JR.
Staff Director
Subcommittee on Energy Research
and Production

JVD/whw
Enclosure

QUESTIONS SUBMITTED BY CHAIRMAN BOUQUARD

1. Can any of the AIS processes be used to treat nuclear wastes, and if so, does DOE have any program investigating this application?

2. Where do we stand in relation to other nations in the development of the AIS technologies? Are we clearly in the lead? What are other nations doing in this arena?

3. What level can we reduce the tails assay using AIS? How can these technologies stretch our uranium resources, and what would be the impact on our ability to maintain viable uranium mining and milling industries?

4. Section 6.1 of the Advanced Isotope Selection Criteria dated August 13, 1981, stated that an AIS proliferation assessment would be prepared by an independent contractor.

   a) Who prepared this assessment and what were the results obtained for each of the three processes?

   b) How easily could a plant employing each of the processes be diverted for production of highly enriched uranium?

   c) How easy would it be to construct clandestinely a small plant producing highly enriched uranium using these processes?

5. The Energy Research Advisory Board's Study Group on Advanced Isotope Separation recently concluded: "There has not been sufficient progress to provide a firm scientific, technical or economic basis on which to select one of three competing processes for full-scale engineering development at this time." Would you please comment on this?

6. Please comment on the following ERAB statement: "We do not believe that the three AIS processes can be evaluated intelligently in isolation from the gas centrifuge program (GCEP or AGC)."

7. ERAB also stated: "Furthermore, in that funding for the special (plutonium) isotope program will be nearly comparable to that of the (uranium) AIS program in FY 1983, decisions affecting uranium AIS development should not be made independently of the plutonium program." Please comment.

8. DELETED.

9. Dr. Leiss and Mr. Voigt, both PSP and AVLIS require the development and application of process facilities for production of uranium metal and for reconversion of enriched uranium metal to a form suitable for reactor fuel. What steps will the Department be taking to assure that these process facilities will be available, or are you assuming that the private sector will automatically be responding to provide this expertise?

10. Dr. Leiss, you state that DOE should fund a continuing peer review. Do you plan on continually evaluating AVLIS versus PSP, or AVLIS versus PSP versus the advanced gas centrifuge technology? What exactly is the scope and magnitude of this peer review process, and how much would it cost?

11. Dr. Leiss, the PEB made four recommendations regarding a PSP R&D program. Should these activities be carried on in parallel, and if so, at what level of effort? Is one of these technical issues a "show-stopper" in the sense that the process would not be viable if the issue were not resolved?

Question 1: Can any of the AIS processes be used to treat nuclear wastes, and if so, does DOE have any program investigating this application?

Answer 1: The use of laser technology in the treatment of the high level radioactive wastes has been considered as part of the AIS program. A small research program at the Naval Research Laboratory (NRL) examined the possibility of partitioning certain long lived from short lived isotopes. NRL was able to show that such a scheme is technically feasible, and analyses indicated that the cost of such a process would not provide significant benefits in terms of the handling of nuclear wastes.

Question 2: Where do we stand in relation to other nations in the development of the AIS technologies? Are we clearly in the lead? What are other nations doing in this arena?

Answer 2: As in the United States, the status of the development of uranium Advanced Isotope Separation (AIS) technology is not generally publicized. Therefore, it is difficult to make a judgment regarding the status of the U.S. program compared with those of other nations. The countries which we know have AIS research programs, from their published reports, are: USSR, France, United Kingdom, Japan, Federal Republic of Germany, People's Republic of China, and Canada.

Question 3: What level can we reduce the tails assay using AIS? How can these technologies stretch our uranium resources, and what would be the impact on our ability to maintain viable uranium mining and milling industries?

Answer 3: The tails assay of any enrichment technology is an economic optimization involving the trade off of the cost of enrichment and the cost of feed material. The current operating tails assay is 0.20 weight percent U-235. The optimum tails assay for the AVLIS process is less than 0.1 weight percent U-235. With this lower tails assay the effective uranium ore utilization is increased by about 20 percent. As AIS technology is phased into the enrichment complex the annual growth in demand for uranium ore would become lower.

Question 4: Section 6.1 of the Advanced Isotope Selection Critiera dated August 13, 1981, stated that an AIS proliferation assessment would be prepared by an independent contractor.

(a) Who prepared this assessment and what were the results obtained for each of the three processes?

(b) How easily could a plant employing each of the processes be diverted for production of highly enrichment uranium?

(c) How easy would it be to construct clandestinely a small plant producing highly enriched uranium using these processes?

Answer 4: (a) The AIS Program Proliferation Assessment was prepared by Professosr Marvin M. Miller, Manson Benedict, and George W. Rathjens, Jr., who are or were associated with the Massachusetts Institute of Technology. They developed the Assessment as consultants under an Oak Ridge Operations Office subcontract funded by the AIS Office.

Based on exrapolation of low enriched (LEU) AIS plant designs and preprototype systems performance, the authors conclude that, like all enrichment proceses, the AIS LEU designs could be adapted to the production of high enriched uranium starting with natural uranium as feed.

(b) All AIS plant concepts are safeguardable. If the IAEA were permitted limited and specified access to specified areas of an AIS plant process building, then the Agency would be able to detect the production of uranium enriched beyond the level needed for light water reactors.

(c) This question cannot be answered on an unclassified basis.

Question 5: The Energy Research Advisory Board's Study Group on Advanced Isotope Separation recently concluded: "There has not been sufficient progress to provide a firm scientific, technical or economic basis on which to select one of three competing processes for full-scale engineering developent at this time." Would you please comment on this?

Answer 5: There is always a risk in selecting a process. While it is true that major uncertainties exist for all three AIS technologies, a firm scientific, technical, and economic basis for any of the three AIS technologies can only be developed by pursuing each technology through another significant scale-up step. This would require about $200 to $400 million per process and about 4 - 6 years; the range of funding and time is a function of the scope of the scale-up step. In the judgment of the Process Evaluation Board (PEB), the risk associated with the AVLIS process in attaining the AIS program goal was significantly lower than PSP or MLIS.

Question 6: Please comment on the following ERAB statement: "We do not believe that the three AIS processes can be evaluated intelligently in isolation from the gas centrifuge program (GCEP or AGC)."

Answer 6: The PEB was requested to evaluate the three AIS technologies and recommend which process should be selected to continue engineering development. As we have testified before, without GCEP, the U.S. will price itself out of the enrichment business. Even at reduced demand levels, the cost of production from GCEP in current year dollars will be significantly lower than production from the existing electricity intensive gaseous diffusion plants (GDPs). When escalation is factored in, the difference between GCEP and GDPs becomes very large. The rapid deployment of enrichment technologies capable of reducing U.S. production costs is a necessary and prudent business decision. Our centrifuge technology is the most advanced proven enrichment technology in the world and offers the U.S. the opportunity to halt the erosion in our existing enrichment contract base and to regain its leadership and market share in the international nuclear community.

We have recently reorganized the Headquarters uranium enrichment and assessment organization. As part of the reorganization, I have established a Technology Office which is responsible for both centrifuge and AIS development. Future evaluation will consider both AIS and centrifuge.

Question 7: ERAB also stated: "Furthermore, in that funding for the special (plutonium) isotope program will be nearly comparable to that of the (uranium) AIS program in FY 1983, decisions affecting uranium AIS development should not be made independently of the plutonium program." Please comment.

Answer 7:

Mr. Voigt

At the start of FY 1982 each laboratory (Los Alamos, Livermore, and TRW) was requested to plan the financial aspects (operating dollar) of their uranium Advanced Isotope Separation (A)S Program on the basis of not being selected. The selected process was to be awarded $3.5 million additional funding for the remainder of the year, which is about 15 percent additional funds. Based on the evaluations conducted by the Process Evaluation Board (PEB), the Atomic Vapor Laser Isotope Separation (AVLIS) process was determined to be the clear front runner for uranium enrichment. The uncertainties associated with the Plasma Separation Process (PSP) and Molecular Laser Isotope Separation (MLIS) process did not warrent selecting these processes as the single process to proceed with engineering development for the uranium AIS program. Since the PSP program is being pursued as a backup, there is no impact to the SIS program. The amount of overlap between AIS and SIS for the MLIS process is very small. The MLIS SIS program has been given first priority on any equipment remaining with the MLIS-AIS program.

Mr. Roser:

The FY 1983 DOE request for the plutonium SIS program is $40 million and that for the uranium AIS program is $34 million. DOE felt that the requirements for the two programs were sufficiently different that the AIS and SIS process selections could be made independently.

**Question 8:** Question 8 is classified

Question 9: Dr. Leiss and Mr. Voigt, both PSP and AVLIS require the development and application of process facilities for production of uranium metal and for reconversion of enriched uranium metal to a form suitable for reactor fuel. What steps will the Department be taking to assure that these process facilities will be available, or are you assuming that the private sector will automatically be responding to provide this expertise?

Answer 9: Dr. Leiss:

We considered that subject in our evaluation by considering the highest cost case of using a $UF_6$ economy. In this scenario $UF_6$ is shipped by the utility to an enrichment plant where it is converted to uranium metal, enriched to the required assay, and converted back to $UF_6$. In this approach, the utility would see no difference in the current industrial involvement in the non-enrichment service.

Mr. Voigt:

The approach described by Dr. Leiss could be the highest cost alternative and was the proper approach to use for process selection. There could be significant enrichment contract perturbations in other alternatives, none of which have we studied in depth. We are aware of the need for additional processing facilities and will be included in our planning basis.

Question 10: Dr. Leiss, you state that DOE should fund a continuing peer review. Do you plan on continually evaluating AVLIS versus PSP, or AVLIS versus PSP versus the advanced gas centrifuge technology? What exactly is the scope and magnitude of this peer review process, and how much would it cost?

Answer 10: Dr. Leiss:

The basis for this recommendation is the recognization by the PEB that the Peer Review process made significant contributions to the AIS R&D programs and to the identification and detailed technical evaluation of issues and subsequent use by the PEB during the evaluation of the processes. In fact, the PEB would have found its job almost impossible without the Peer Review process. A panel of expert consultants meeting on an occasional basis cannot equal the contribution that a contiuous Peer Review looking in-depth at the scientific and engineering issues can make it a high technology program.

The near term major peer review activity of the AVLIS program will culminate in early 1984 when the design point for the DDM is evaluated. If the results of the evaluation shows an acceptable risk, DOE will release design funds for the DDM. PSP could also undergo a peer review during this period. These efforts would cost several million dollars per year. The PEB limited its evaluation activity to AIS only. Mr. Voigt should answer questions on gas centrifuge.

Mr. Voigt:

We do not consider the PSP process as a competitor to the gas centrifuge, but rather a back-up to AVLIS. The next major technology selection will be between AVLIS and AGC for additional production capacity after GCEP. Since the AVLIS program benefited from the peer review process, we are considering extending this to the gas centrifuge program.

Question 11: Dr. Leiss, the PEB made four recommendations regarding a PSP R&D program. Should these activities be carried on in parallel, and if so, at what level of effort? Is one of these technical issues a "show-stopper" in the sense that the process would not be viable if the issue were not resolved?

Answer 11: Our conclusion on the PSP process to achieve the AIS goal of less than $40/SWU was marginal if physics issues are resolved favorably. We also concluded that it would require process designs using higher magnetic fields. Substantial procgress toward resolving these questions can be made in a carefully focused R&D program utilizing the present preprototype magnet. Elements of this program would include: demonstration of present process performance with full aperture and fully density plasma; development and demonstration of improved drive coil configurations where substantial improvement seems possible; investigation of resonance line width dependence on magnetic field to provide assurance that projected improved process performance at higher magnetic field is possible; and investigation of radial scaling of drive field and possible drive coil geometries which would reduce radial dependence of drive field.

Technically, all of these efforts can be evaluated in parallel and substantial progress could be made over a two year period. Significant progress must be made for PSP to be in a good position as a back-up technology.

The PEB recognizes a major problem in making this recommendation. In a generic sense, the carrying of a back-up technology implies a competition for funding and usually an adverse effect on the primary technology effort. Thus, if funding restrictions do hinder the mainline AVLIS program effort, the PEB would not make this recommendation.

DON FUQUA, FLA., CHAIRMAN

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD BOUQUARD, TENN.
JAMES J. BLANCHARD, MICH.
DOUG WALGREN, PA.
RONNIE G. FLIPPO, ALA.
DAN GLICKMAN, KANS.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
RICHARD C. WHITE, TEX.
HAROLD L. VOLKMER, MO.
HOWARD WOLPE, MICH.
BILL NELSON, FLA.
STANLEY N. LUNDINE, N.Y.
ALLEN E. ERTEL, PA.
BOB SHAMANSKY, OHIO
RALPH M. HALL, TEX.
DAVE MCCURDY, OKLA.
MERVYN M. DYMALLY, CALIF.

LARRY WINN, JR., KANS.
BARRY M. GOLDWATER, JR., CALIF.
HAMILTON FISH, JR., N.Y.
MANUEL LUJAN, JR., N. MEX.
HAROLD C. HOLLENBECK, N.J.
ROBERT S. WALKER, PA.
EDWIN B. FORSYTHE, N.J.
WILLIAM CARNEY, N.Y.
MARGARET M. HECKLER, MASS.
F. JAMES SENSENBRENNER, WIS.
VIN WEBER, MINN.
JUDD GREGG, N.H.
RAYMOND J. MCGRATH, N.Y.
JOE SKEEN, N. MEX.
CLAUDINE SCHNEIDER, R.I.
JIM DUNN, MICH.
BILL LOWERY, CALIF.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

HAROLD P. HANSON
EXECUTIVE DIRECTOR

ROBERT C. KETCHAM
REGINA A. DAVIS
MARTHA KREBS
GEORGE S. KOPP
JOHN V. DUGAN, JR.
THOMAS H. MOSS
DARRELL R. BRANSCOME
ANTHONY C. TAYLOR
ROBERT B. NICHOLAS

GERALD E. JENKS
MINORITY STAFF DIRECTOR

June 7, 1982

Mr. Herman E. Roser
Asst. Secty. for Defense Programs
U.S. Department of Energy
Washington, D.C. 20585

Dear Mr. Roser:

We appreciated having you testify on the Department of Energy's Special Isotope Separation Program at the Subcommittee's FY 1983 budget review hearing on May 20, 1982. Chairman Bouquard would like to supplement the record of the hearing with some additional questions she has regarding the program. We request that your replies be prepared in both a classified version, where appropriate, and in an unclassfied version which can be made a part of the public record. We appreciate your cooperation on this matter and we hope that this information can be provided by June 21, 1982.

If you have any general questions regarding this request, please contact me at 225-8056. If you have any questions regarding the specifics, please contact Dr. Harlan Watson of the Subcommittee staff at 225-3472.

Sincerely,

John V. Dugan Jr.

JOHN V. DUGAN, JR.
Staff Director
Subcommittee on Energy Research
and Production

JVD/whw
Enclosure

## QUESTIONS SUBMITTED BY CHAIRMAN BOUQUARD

1. Mr. Roser, on page 2 of your statement, you say that you (DELETED) Would you elaborate on this statement? How would you propose to obtain nuclear materials in excess of current or planned production levels?

2. Mr. Roser, you presented graphs depicting plutonium production requirements to meet the forecasted outyear requirements of the latest Nuclear Weapons Stockpile Memorandum, signed by the President on March 17, 1982. What are the Memorandum requirements for highly enriched uranium, and will we be able to meet these requirements by drawing down current stockpiles and by production using the gaseous diffusion plants?

3. Can any of the SIS processes be used to separate tritium from the heavy water used in the Savannah River production reactors or in the Candu reactors to reduce radiation exposure for reactor operating and maintenance personnel, and if so, does DOE have any program investigating this application?

4. Where do we stand in relation to other nations in the development of the SIS technologies? Are we clearly in the lead? What are other nations doing in this arena?

5. The Energy Research Advisory Board's Study Group on Advanced Isotope Separation recommended: "...in that funding for the special (plutonium) isotope program will be nearly comparable to that of the (uranium) AIS program in FY 1983, decisions affecting uranium AIS development should not be made independently of the plutonium program." Please comment.

## House Science and Technology Questions and Answers

Question: How would you propose to obtain nuclear materials in excess of current or planned production levels?

Answer: To meet the requirements, it will be necessary to take the following actions:

Utilize presently programmed production capacity: The three currently operating reactors at Savannah River, South Carolina; L Reactor at Savannah River which will be operating in FY 1984; N Reactor at Richland, Washington, which will be fully converted to weapon-grade plutonium production in FY 1984; and blend previously produced fuel-grade plutonium from N Reactor with high-purity plutonium specially produced in the Savannah River reactors. Additional fuel-grade blend-stock plutonium and weapon-grade plutonium from N Reactor will both become available for use starting in FY 1984, when the PUREX fuel processing plant at Richland, Washington, comes on-line.

Further increases of weapon-grade plutonium can be achieved with the following new production initiatives: Utilization of higher productivity cores in the Savannah River reactors; enhancement of the productivity of N Reactor; and modification of a fuel processing plant at Richland, Washington, or Savannah River, South Carolina, to recover plutonium from DOE nonproduction reactor fuel elements, which then can be converted into weapon-grade plutonium in a special isotope separation (SIS) facility presently under development.

The SIS facility would clean up DOE-owned plutonium to weapon-grade purity including N Reactor fuel-grade plutonium and other DOE-owned plutonium such as that from DOE-owned nonproduction reactor spent fuels, e.g., the Fast Flux Test Facility.

House Science and Technology Questions and Answers

Question: Mr. Roser, you presented graphs depicting plutonium production requirements to meet the forecasted outyear requirements of the latest Nuclear Weapons Stockpile Memorandum, signed by the President on March 17, 1982. What are the Memorandum requirements for highly enriched uranium, and will we be able to mee these requirements by drawing down current stockpiles and by production using the gaseous diffusion plants? Mr. Voigt, you should also feel free to comment here.

Answer: Mr. Roser: The forecasted incremental requirements for highly enriched uranium (HEU) in the latest Nuclear Weapons Stockpile Memorandum, which covers F 1983-97, takes into account HEU recovered from retired weapons. This represents an augmentation of the current Department of Energy (DOE) stockpile. The DOE plans to meet these requirements by producing additional HEU in the gaseous diffusion plant at Portsmouth, Ohio.

House and Science Technology Questions and Answers

Question: Mr. Roser, can any of the SIS processes be used to separate tritium from the heavy water used in the Savannah River production reactors or in the CANDU reactors to reduce radiation exposure for reactor operating and maintenance personnel, and if so, does DOE have any program investigating this application?

Answer: Yes, Special Isotope Separation technology could be used to separate tritium from the heavy water used in the Savannah River production reactors. We have a small-scale research and development program on advanced tritium separation technology underway at Livermore.

House and Science Technology Questions and Answers

Question: Where do we stand in relation to other nations in the development of the AIS and SIS technologies? Are we clearly in the lead? What are other nations doing in this arena?

Answer: As in the United States, the status of the development of uranium Advanced Isotope Separation (AIS) and plutonium Special Isotope Separation (SIS) technology is not generally publicized. Therefore, it is difficult to make a judgment regarding the status of the United States program compared with those of other nations.

We do know that other countries have small scale research programs underway on uranium AIS technology and plutonium SIS technology. The countries which we know have Laser Isotope Separation researach programs from their published reports are: USSR; France; United Kingdom; Japan; Federal Republic of Germany; People's Republic of China; and Canada.

## House Science and Technology Questions and Answers

Question: Mr. Voigt and Mr. Roser, ERAB also stated: "Furthermore, in that funding for the special (plutonium) isotope program will be nearly comparable to that of the (uranium) AIS program in FY 1983, decisions affecting uranium AIS development should not be made independently of the plutonium program." Please comment.

Answer: Mr. Voigt: At the start of FY 1982 each laboratory (Los Alamos, Livermore, and TRW) was requested to plan the financial aspects (operating dollar) of their uranium Advanced Isotope Separation (AIS) program on the basis of not beingselected. The selected process was to be awarded $3.5 million additional funding for the remainder of the year, which is about 15 percent additional funds. Based on the evaluations conducted by the Process Evaluation Board, the Livermore Atomic Vapor Laser Separation process was determined to be the clear front runner for uranium enrichment. The uncertainties associated with the TRW Plasma Separation Process and the Los Alamos Molecular Laser Isotope Separation (MLIS) process did not warrant selecting these processes as the single process to proceed with engineering development for the uranium AIS program.

Mr. Roser: The FY 1983 DOE request for the plutonium Special Isotope Separation (SIS) program is $40 million and that for the uranium AIS program is $34 million. The Department of Energy (DOE) felt that the requirements for the two programs were sufficiently different that the AIS and SIS process selections could be made independently.

# APPENDIX V

## Additional Material Submitted for the Record

U.S. DEPARTMENT OF ENERGY
OFFICE OF PUBLIC AFFAIRS
WASHINGTON, DC 20585

**DOENEWS:**

FOR IMMEDIATE RELEASE
April 30, 1982

### ADVANCED ISOTOPE SEPARATION PROCESS SELECTED FOR DEVELOPMENT & DEMONSTRATION

The Department of Energy has selected an advanced technique for enriching uranium, the Atomic Vapor Laser Isotope Separation (AVLIS) process, for large-scale engineering development and demonstration.

The AVLIS process is under development at the department's Lawrence Livermore National Laboratory in Livermore, Calif., with technical support from the Union Carbide Corporation Nuclear Division in Oak Ridge, Tenn. This process is one of three approaches for separating uranium isotopes that the Department has been evaluating.

The other two processes are known as the Plasma Separation Process, being developed by TRW, Inc., of Redondo Beach, Calif.; and the Molecular Laser Isotope Separation process, being developed at the department's Los Alamos National Laboratory in New Mexico. In addition to the AVLIS research and development effort, the department will continue to provide support for research on the Plasma Separation Process. Research on the three processes has been going on for more than five years.

All three technologies are based on the concept that different uranium isotopes selectively absorb radiation in different regions of the energy spectrum. This selective absorption can then be used to separate the desired uranium isotope. The uranium enrichment process increases the concentration of the isotope U-235 in natural uranium. This "enriched" uranium can then be fabricated into a fuel for use in conventional nuclear reactors.

In the AVLIS process, uranium metal is used as a feed material. A uranium vapor stream is created, and the stream is then energized with lasers. Selectively ionized U-235 atoms are collected by an electromagnetic field to become an enriched product, while the neutral U-238 atoms pass through to a collector for depleted uranium.

The AVLIS technology was recommended for further development as a result of an in-depth, seven-month review of the three competing technologies by a process evaluation board, with members from the department's Office of Energy Research, Office of Nuclear Energy, and Oak Ridge (Tenn.) Operations Office.

The board rated each of the three competing processes on the basis of designs proposed for a development module and an actual production plant; expected process performance and risks; relative economic potential; and overall program management capabilities.

In developing the AVLIS process, scientists will initially focus on resolving technical performance issues. When this is accomplished, the department will proceed with the design, construction and operation of a development/demonstration module, which will establish the engineering feasibility of the process and provide a firm base for cost projections. The demonstration module should be operational by 1987.

The Plasma Separation Process research will make use of the superconducting magnet system which is already operational at the TRW facility to investigate how the enrichment process would be affected by changes in the size of the magnet and its components. This research also will be aimed at developing improved methods for providing energy to the U-235 isotope, in order to make the enrichment process more efficient. The results of this program will support departmental objectives. Final program levels are subject to availability of funds.

Advanced isotope separation technology offers the greatest promise of providing enriched uranium at a reduced cost.

By 1990, the department expects to choose either the advanced gas centrifuge technique -- another advanced enrichment technology which has the potential to lower enrichment costs -- or the AVLIS process for possible replacement of the existing gaseous diffusion enrichment plants and for providing new enrichment capability.

The department's uranium enrichment activities are managed by the Assistant Secretary for Nuclear Energy.

- DOE -

News media contact: Philip A. Garon, 202-252-4399

# UNCLASSIFIED EXCERPTS FROM THE
# PROCESS EVALUATION BOARD"S ASSESSMENT OF THE ADVANCED ISOTOPE SEPARATION PROGRAM

APRIL 30, 1982

## 1.0 Overview

### 1.1 AIS Program

The goal of the Department of Energy uranium enrichment program is to meet domestic, foreign, and U.S. Government requirements for uranium enrichment services in the most economical, reliable, safe, and environmentally acceptable manner. To meet this goal the Department operates three gaseous diffusion plants using technology developed in the 1940's. It also has under construction a gas centrifuge enrichment plant and is continuing research and development on advanced gas centrifuge systems which will provide enrichment services at reduced total cost and use substantially less electric power than the operating gaseous diffusion plants.

For several years, the Department has also carried out an Advanced Isotope Separation (AIS) research and development program to explore new alternative methods for uranium isotopic enrichment. The goal of this AIS program is primarily economic; to develop a new technology which will produce enriched uranium at substantially lower enrichment cost than present processes. The target established for the program is to produce enriched uranium at an enrichment cost of less than $40/SWU. Successful development and implementation of this technology would represent a substantial productivity improvement in the enrichment business. Benefits of the lower enrichment cost would support the following missions:

- Replace power intensive gaseous diffusion plants

- Supply additional separative work capacity as required for expansion of nuclear power

- Lower the tails assay of the United States enrichment enterprise economically

- Increase the U.S. competitive position in the world uranium enrichment market.

Research and development on three different AIS technologies has been underway for several years. The FY 1982 program budget was about $86 million dollars. These three technologies are the Atomic Vapor Laser Isotope Separation (AVLIS) process, the Molecular Laser Isotope Separation (MLIS) process, and the Plasma Separation Process (PSP). Two of these processes, AVLIS and PSP, utilize uranium metal as the input feedstock, while the third, MLIS, utilizes uranium hexafluoride, $UF_6$.

R&D on the AVLIS process is carried out primarily at the Lawrence Livermore National Laboratory (LLNL) with assistance of the Union Carbide Corporation Nuclear Division (UCC-ND). The process exploits the fact that isolated and isotopically unique atomic transitions in U-235 can be identified and excited by photons with very little excitation of atomic states in U-238. Several prescribed photon energies are used to excite U-235 to ionization. The uranium ions thus produced are collected electrostatically.

MLIS process R&D is carried out primarily at the Los Alamos National Laboratory (LANL) with assistance of UCC-ND. The process utilizes $UF_6$ gas and exploits that $UF_5$ is a solid at room temperature and that the probability for UV photons to remove a flourine atom from $UF_6$ to produce $UF_5$ is enhanced for those $UF_6$ molecules which have been excited from intermediate vibrational states relative to photodissociation from the ground state. Isotopic selectivity is achieved by IR photon excitation of supercooled $UF_6$ vibrational states at a photon energy where the absorption by $^{235}UF_6$ is enhanced relative to that for $^{238}UF_6$.

R&D on the PSP process is carried out primarily by TRW, Inc. with assistance by UCC-ND. This process utilizes plasmas of uranium ions confined in a solenoidal magnetic field. The process exploits the fact that the ion cyclotron resonance frequency for U-235 ions differs from that for U-238 ions. A radiofrequency field tuned to the U-235 ion cyclotron frequency will preferentially impart energy to the U-235 ion stream, thereby increasing the diameter of its orbit. The U-235 ions are collected using both geometric differences in the two ion type orbits and electrostatic repulsion of the lower energy U-238 ion stream.

Each of these three efforts has demonstrated a capability for uranium enrichment. Furthermore, each has achieved substantial progress in understanding the problems which must be solved in carrying their R&D program forward to a production plant.

### 1.2 AIS Process Selection

Future progress in developing the potential of each process requires the construction of new research and development facilities and, in some cases, the initiation of substantial hardware development programs. Multi-year program development plans proposed by the process proponents reflect these requirements, and indicate the need for substantially increased AIS program funding in FY 1984 and beyond if all three processes are to be developed. These financial needs, together with the progress achieved in the program, have led the DOE program management to conclude that by mid-FY 1982 one of the three processes should be selected for further development and engineering scaleup. To carry out this selection process an extensive program review has been underway for several months.

A Process Evaluation Board (PEB) comprised of Department of Energy employees has been formed to provide input to the AIS program management on this program review and process selection. The purpose of the PEB is to:

- o Conduct indepth review and evaluations of each of the three competing processes, and
- o Recommend which process should proceed toward full scale engineering development.

In accepting its charge, the PEB unanimously agreed that the Board would recommend selection of that process which has the greatest economic potential and the least risk of failure. The PEB recognized the value of selection criteria prepared by the AIS program office as a framework for the evaluation of the competing technologies but also recognized that changes might be required as the evaluation process proceeded. The PEB proposed to focus on the following questions in its assessment activities:

- What are the prospects for successful engineering development?
- Is the technical base adequate to procede to the next step in process scaleup?
- Do the projected economics of the technology meet the AIS program goals?
- Is there flexibility within the technology and in the design of large facilities sufficient to overcome potential problems?
- Does the proposed Development Module provide adequate confidence that will enable DOE to commit to the deployment of the technology?
- Are the program plans, schedules, and costs realistic?

This report presents the evaluations, conclusions, and recommendations of the Process Evaluation Board and is unanimously agreed to by its members.

### 2.1.4 Summary Evaluation

As a result of the observations presented above and the technical and economic evaluations presented in Section 4 of the report, the PEB assessment of the three AIS processes is summarized in Table 2.1.4. The PEB evaluation indicates that there is reasonable probability that the AVLIS process can achieve enrichment costs at less than the economic goals set for the AIS program. The greatest concern is with the thermal control performance of the liquid uranium collector. PEB studies indicate that even if the AVLIS vapor flux is reduced to the point where the present collector performance is reasonably assured the enrichment cost still remains attractive. However, the PEB does note that until a clear resolution of AVLIS collector performance issues are resolved, it would be difficult to justify proceeding with actual construction of a Development/Demonstration Module.

Table 2.1.4

## Evaluation of Process & Plant Designs

| Process | Completeness of Plant Description | Changes During PEB Process | Overall Assessment | Prospects for <$40/SWU Process |
|---|---|---|---|---|
| AVLIS | Reasonable, But Lacking in Detail | Stable<br>• Reinsertion 1st Color<br>• Optimization Calls for Increased Standoff | Adequate; Principal Questions Are With Technical Performance, Especially Collector Thermal Design | Reasonable if Collector Thermal Design & Performance Issues Resolved |
| PSP | Reasonably Detailed | Stable<br>• Source Changes<br>• Microwave Heating Design<br>• Drive Field Coil Design<br>• More Complete Physics Model | Adequate; Principal Questions Are With Performance Physics, Especially Those of Radial Scaling of Module | Marginal if Physics Issues Resolved Favorably. Probably Would Require Design Using Higher Magnetic Field |
| MLIS | Repeated Changes Make Plant Description Unclear | Radical Changes<br>• 3 Infrared Lasers<br>• New Nozzle Design<br>• Changed Optical Design<br>• Increased Rep Rate | Less Than Adequate; Many Physics and Technical Issues Which Could Have Large Cost Impact | Impossible to Determine at This Time. |

The PEB evaluation indicates that there is marginal probability that the PSP process can achieve enrichment costs at less than the economic goals set for the AIS program. The greatest technical concerns are with process physics issues related to radial scaling of the plasma to baseline diameters. The PEB recognizes the potential of improvements which could be made to reduce PSP enrichment costs. These improvements, as well as favorable resolution of physics issues, would probably be required to achieve favorable enrichment costs.

The PEB finds it essentially impossible to determine at this time the probability that the MLIS process can achieve enrichment costs at less than the economic goals set for the AIS program. However, the PEB does note that the baseline enrichment costs for the MLIS process are very close to the AIS economic goals. Further, the MVSS studies indicate greater enrichment costs. The PEB also notes that a number of sources of possible MLIS process performance degradation previously discussed are not contained as variables in MVSS studies.

## 2.2 Recommendations of the PEB

As a result of its evaluations, and in consideration of its charge, the PEB makes the following recommendations and comments on these recommendations:

> Recommendation 1
>
> It is recommended that the AVLIS process be selected to proceed into the next phase of the RD&D program. While there are significant risks related to the operation of the separation unit as currently configured, particularly in the area of thermal control of the uranium collector, it is the judgment of the PEB that an AVLIS process meeting the economic goals set for the AIS program can be achieved.

Comment on Recommendation 1-The basis for this recommendation is that it is the judgment of the PEB that the AVLIS process has the best overall prospects for successful engineering development and for meeting the AIS program goal of producing enriched uranium for less than $40/SWU. For example, projections of an AVLIS plant capital cost, power, and $/SWU are lower than the competing processes. There are significant risks in the area of thermal control, design and operation of the liquid uranium collector, and other risks in the areas vapor degradation, laser costs and refurbishment costs. However, the PEB feels that there is flexibility within the technology and the design responses available to achieve success. The PEB is obligated to point out that in making a decision at this time i.e., before large scale experimental confirmation of process performance, there is considerable risk involved. For example, although the PEB has explored the uranium collector thermal control issue through exercising the AVLIS model and finds that no "cliff" could be observed, the Board must consider the fact that there may be significant limitations in the computer models, and that for some areas of concern experimental data at the operating conditions of interest does not exist at this time. It is this situation that leads to other recommendations discussed below.

> Recommendation 2
>
> It is recommended that funds for detailed design and construction of the AVLIS demonstration module not be released by DOE until uncertainties in the design and operation of the uranium collector subsystem are resolved. This will help assure that the DDM is, as nearly as possible, a prototypic plant module.

Comment on Recommendation 2-The basis for this recommendation is the strong feeling of the Board that the Development/Demonstration Module should be a prototype module of a plant. By virtue of having the DDM as close to a prototype module of the plant as possible, successful operation of the DDM will provide the confidence necessary for DOE to commit to the large capital outlays necessary for deployment of the technology, and would provide DOE with reliable knowledge of plant enrichment costs. The PEB recognizes the need to minimize the time to construct and to bring into operation the DDM, and yet the need to reach satisfactory resolution of the uranium collector thermal design issue before detailed design and construction of the DDM is initiated.

While the Board concludes that an economically acceptable uranium collector can be developed, the detailed configuration of the DDM might be modified as this issue is resolved. Specifically, the PEB is concerned that the long leadtime involved in the budget process not add to the time required to resolve the above uncertainties. The PEB therefore would encourage inclusion of the DDM in the budget planning process, but recommends only constraint on release by DOE of appropriated DM construction funding.

> Recommendation 3
>
> It is recommended that the near term AVLIS RD&D program emphasize resolving the uranium collector subsystem issues. This is important since early initiation of detailed design and construction of the DM will reduce the overall RD&D costs and time schedule.

Comment on Recommendation 3-The basis for this recommendation is the clear need to resolve the one issue that in the judgment of the PEB is the major risk factor in the AVLIS process. It is the judgment of the Board that a clearly focused RD&D program to resolve the uranium collector subsystem issues can be established and completed within the next 18 to 24 months.

> Recommendation 4
>
> It is recommended that the Department of Energy consider supporting a limited RD&D program on the PSP process to exploit and optimize the performance of the PSP process preprototype. Within the operational limitations of the preprototype magnet this will enable the PSP process to be in a good position as a backup technology. The PEB does not recommend this action if funding limitations are such that carrying this backup technology delays the mainline AVLIS program effort.

Comment on Recommendation 4-The basis for this recommendation is the clear recognition that the PEB could be wrong in its evaluation of the AVLIS process. There may be factors that have not been identified by the Peer Review or by the evaluation by the PEB. Thus, the Board recognizes the value of considering a backup technology that would be continued in a limited R&D mode and be available if the AVLIS process is shown in the future to be incapable of achieving the AIS program goals. It is the judgment of the PEB that the PSP process has the next best prospects for successful engineering development and technological deployment if the advanced concepts which have been proposed by PSP proponents can be successfully carried out, and if present uncertainties in PSP process performance can be resolved successfully. Substantial progress toward resolving these questions can be made in a carefully focused R&D program utilizing the present preprototype magnet. Elements of this program would include: demonstration of present process performance with full aperture and full density plasma; development and demonstration of improved drive coil configurations where substantial improvement seems possible; investigation of resonance line width dependence on magnetic field to provide assurance that projected improved process performance at higher magnetic field is possible; and investigation of radial scaling of drive field and possible drive coil geometries which would reduce radial dependence of drive field. The PEB feels that substantial progress on this R&D effort could be made over the next two years, and, if successful, would allow the PSP process to be in a good position as a backup technology.

The PEB recognizes a major problem in making this recommendation. In a generic sense, the carrying of a backup technology implies a competition for funding and usually an adverse effect on the primary technology effort. Thus, if funding restrictions do hinder the mainline AVLIS program effort, the PEB would not make this recommendation.

> Recommendation 5
>
> It is recommended that the AIS program office fund a continuing peer review that provides assistance in identification and detailed evaluation of scientific, technical, and engineering issues in the AIS program.

Comment on Recommendation 5-The basis for this recommendation is the recognition by the PEB that the Peer Review process made significant contributions to the AIS R&D programs and to the identification and detailed technical evaluation of issues and subsequent use by the PEB during the evaluation of the processes. In fact, the PEB would have found its job almost impossible without the Peer Review process. A panel of expert consultants meeting on an occasional basis cannot equal the contribution that a continuous Peer Review looking in-depth at the scientific and engineering issues can make in a high technology program.

# REPORT

# OF THE

# ENERGY RESEARCH ADVISORY BOARD

# STUDY GROUP

# ON

# ADVANCED ISOTOPE SEPARATION

April 1982

## 1. EXECUTIVE SUMMARY

The Study Group briefly reviewed the technical status of the three Advanced Isotope Separation (AIS) processes, with emphasis on the progress that has been made during the year and a half since it submitted a detailed report on this topic. It also reviewed the evaluation work that has been carried out by DOE's Process Evaluation Board (PEB) and the Union Carbide Corporation-Nuclear Division (UCCND). The Study Group briefly reviewed a recent draft assessment made for DOE staff of the nonproliferation implications of the AIS technologies. The staff also very briefly summarized the status of GCEP and Advanced Centrifuge development.

Conclusions:

Based on its review, the Study Group concludes that:

1.1 (a) There has not been sufficient progress to provide a firm scientific, technical or economic basis on which to select one of the three competing AIS processes for full-scale engineering development at this time.

1.1 (b) However, should budgetary restraints or other factors force such a selection, we believe that the evaluation process that is being carried out by the PEB provides the best basis available for making a decision at this time between the processes within the constraints of the charge to the Study Group, that is, a) excluding any consideration of the relationship between the uranium and plutonium AIS programs and b) excluding comparison of the AIS technologies at this time with advanced gas centrifuge technology.

Recommendations:

The Study Group recommends that:

1.2 (a) Any decisions on AIS processes should include a comparison with the gas centrifuge processses, and should not be made independently from the plutonium isotope program.

1.2 (b) In evaluating the various enrichment processes, all applicable costs (including R&D and sales overhead) and an appropriate discounting approach should be included in order to make comparisons on a "private industry" basis.

1.2 (c) If the uranium enrichment enterprise is to remain competitive with foreign suppliers, it should be made an independent self-financing agency similar to TVA, or other private or quasi-governmental organizational structure, as recommended previously by the Study Group.

1.2 (d) If the three AIS programs continue with limited resources, the work should be reoriented to focus only on the most pressing technical problems, selected by DOE management after considering those identified by the Process Evaluation Board. This could materially delay the ultimate deployment of a potentially low-cost per SWU enrichment process, with similar delay in the potentially very large cost benefits.

1.2 (e) The Multi-Variable Sensitivity Study of the processes being carried out by Union Carbide should be extended to accommodate fallback technology sub system options for each process.

1.2 (f) If a decision is made to develop the Atomic Vapor Laser Isotope Separation process, the solid collector option should be pursued in parallel to alleviate the potential program impact of liquid collector thermal control problems.

## 2. INTRODUCTION

On March 19, 1982, W. Kenneth Davis, the Deputy Secretary of Energy, requested (see Appendix A) that the Energy Research Advisory Board briefly reexamine the technical status of the Advanced Isotope Separation (AIS) processes and provide him recommendations related to implementing a process decision in April. In his letter, Mr. Davis noted that one recommendation by the 1980 Study Group on this topic was to reduce the number of processes as rapidly as possible as soon as one meets the commercialization parameters of full-scale development and, in any case, by mid-FY 1983.

In response to the request, ERAB reconvened the Study Group on Advanced Isotope Separation for a 1-day meeting on March 31, 1982. The members had all served on the 1980 Study Group, and so were quite familiar with the technologies under development. In addition, the Chairman of the Study Group has visited all three of the contractors within the past month.

The Study Group heard presentations by the following:

1. Each of the three contractors in the presence of the others reported on the technical progress and status of their process. All three contractors were present during the reports, and were invited to comment on each other's processes. The Chairman of the Process Evaluation Board (PEB), DOE staff, and representatives from Union Carbide Corporation-Nuclear Division (UCCND) were also present.

2. The Manager of Union Carbide Nuclear's Advanced Isotope Separation Division reported on the AIS evaluation and the Multi-Variable Sensitivity Study being carried out for the Department. The proponents were present and participated in the discussion that followed. Staff of the three contractors and of UCCND then left the meeting.

3. The Chairman of the Department's Process Evaluation Board, which is charged with conducting an indepth review and evaluation of each of the three competing processes, and with recommending to the Under Secretary which process should proceed toward full-scale engineering development.

4. The Study Group then met in executive session to discuss the information and documents that had been presented. Additional information was provided by DOE staff from the Office of Uranium Enrichment and Assessment on proliferation studies and advanced gas centrifuge work. After deliberation, the Study Group reached a consensus on their conclusions and recommendations.

## 3. BACKGROUND

On May 1, 1980, the Director of Energy Research sent a letter to the Chairman of the Energy Research Advisory Board stating that the Under Secretary had requested ERAB to convene a Study Group to:

> ".....review DOE's Advanced Isotope Separation Program Strategy and the role of Jersey Nuclear-AVCO Isotopes in that program. Specifically, ERAB is requested to review the AVLIS, PSP, MLIS and JNAI processes with respect to:
> - o Overall Advanced Isotope Separation Program Strategy
> - o Current technology state of the art
> - o Future risks, benefits and costs associated with implementation of a particular AIS strategy."

The letter further stated that the ERAB findings would be utilized to assist the Department in the development of an Advanced Isotope Separation Program Plan.

The Study Group was appointed, and carried out a detailed technical review over a period of several months, which included extensive briefings by DOE program staff and 9 days of briefings at the contractor sites.

On November 26, 1980, the Chairman of ERAB submitted the Report of the ERAB Study Group on AIS to the Secretary of Energy. A summary of the ERAB recommendations is shown in Appendix B, together with the Study Group's understanding of how the Department has responded to them during the past year and a half. That Report, listed as Item 1 in the Bibliography, describes the AIS technologies in detail, the organization of the programs and the production alternatives, and contains a glossary of technical terms. It is to be considered as an integral part of this 1982 Report.

Because the Department intends to make an AIS process decision within the month, the Deputy Secretary has requested ERAB to briefly reexamine the technical status of those processes. The results of that review are presented in the following section.

## 4. OBSERVATIONS AND RECOMMENDATIONS

The ERAB Study Group on Advanced Isotope Separation (AIS) reviewed the status of the three remaining AIS programs (AVLIS, MLIS, PSP), the DOE mechanism for evaluation, and the interaction among the three AIS programs and Union Carbide Corporation-Nuclear Division (UCCND) in its role as "honest broker" and evenhanded evaluator of program status and potential. Within DOE, the Process Evaluation Board (PEB), chaired by Dr. James Leiss, is charged with evaluating the three AIS programs and recommending which one should proceed to full-scale engineering development.

Although the time available to review and consider the technical status of the AIS candidate processes relative to that available at the time of our 1980 report was extremely limited, we note that the presentations were well prepared and technically adequate to address the issue raised.

Our principal conclusion is that there is not yet sufficient technical/scientific data available to make a selection of one candidate on a low technical risk basis. All three approaches still have major scientific and technical uncertainties that will not be resolved before the mid to late 1980's, unless major efforts are focussed on their resolution at an earlier date. This situation must be balanced against the potential benefits that could accrue from early development of a process that would provide substantial reductions in the costs of uranium enrichment, as was discussed in some detail in the earlier report of this group (Reference 1). The pressure for selection appears to be driven by a combination of budget limitations at an inappropriate time for the AIS program, the way the programs are structured (e.g., oriented toward expensive demonstration modules instead of resolving only the key scientific uncertainties, and treatment of AIS in isolation from other isotope separation programs). The timing of the decision does not appear to be based on the maturity of the research and development. While a limited budget may force a decision, the Study Group believes that additional funding would lead to a much more firm basis for making a decision in the future.

While major technical uncertainties exist for each process, we consider the following to be a typical example. The most critical potential issue identified for the AVLIS process by the Process Evaluation Board is thermal control stability for the liquid collector modules. The back-up for this is clearly the solid collector, a fact recognized by the program participants, but not formally included in the process comparisons. (The Study Group was given an informal estimate of $5-10/SWU increase if the process is forced to this alternative.) Active pursuit of the solid collector option was apparently abandoned when funding for the JNAI process was stopped in FY 1981, a concern that was expressed by the Study Group in its earlier report. The Study Group recommends that, if the AVLIS process is selected, the solid collector option be pursued in parallel to alleviate the potential program impact of a liquid collector thermal control problem.

The identification of, and general agreement on, such technical problems results from the evaluation efforts carried out by the Union Carbide Corporation-Nuclear Division and by the Process Evaluation Board. UCCND has performed its role for the last 2 years in part by building, maintaining, and operating a computer model which incorporates physics, process variables, costs, and other parameters supplied by the individual programs. It is called the "Multi-Variable Sensitivity Study" (MVSS). A key and very valuable tool has been periodic "peer review" sessions, at which personnel from the three programs have criticized each other's program technically and responded to the criticism of the others. The Study Group is impressed by the rapidity of progress and the effectiveness of mutual education which resulted from this peer review. In addition, UCCND has contributed technically to all three programs: to AVLIS and PSP by technical work on liquid-uranium collectors, and to MLIS by work on uranium hexafluoride handling, operation of a laser flow loop, and the like.

The key role of UCCND in the AIS program, however, has been as custodian of the computer models to provide performance and cost outputs from sets of technical inputs. Three assessment approaches are used: Base Case; Single-Variable Sensitivity Studies; and a Multi-Variable Sensitivity Study (MVSS). These models are very valuable in showing the results of sets of assumptions, and in allowing ranges of parameters to be accommodated in a Monte Carlo fashion, reflecting UCCND judgment of relative probability of success at achieving various parameters. The model is quite complex, however, and since the physics and economics are not completely understood, its results should be viewed with considerable caution.

In any case, MVSS should be extended to accommodate fallback technology sub system options. For example, if a 4 meter in diameter PSP unit should fail because of ion skin depth problems, PSP should be credited with the option (and performance and costs) of 1-meter modules. Similarly, if there is no adequate temperature range for operation of a molten uranium collector in AVLIS, one alternate remedy through the present MVSS is to reduce the atom flux very substantially, with resultant increase in cost per SWU. However, it would be very useful to develop a solid, cooled collector alternative for processing through the MVSS. Care should be taken to ensure that the MVSS for AVLIS includes the possibility of liquid collector system failure, and penalties (contingency, etc.) associated with the possible introduction of a new collector.

The Study Group notes that the charge to the Process Evaluation Board was limited to recommending which of the competing AIS processes should proceed to full-scale engineering development, if a decision is made to reduce the number of competing processes from three to one. We concur with the PEB's approach to technically evaluating the programs relative to each other, and believe their summary of the most significant technical uncertainties is both accurate and aptly put. The summary presented to the Study Group by the Chairman of the PEB is shown below:

## AVLIS Principal Issues

| | Experimental Resolution |
|---|---|
| o Thermal Control of Collector | 6/84 or 9/86 |
| o Collection Efficiency | 6/84 or 9/86 |
| o Vapor Degradation Effects | 6/84 |
| o Laser Costs | ~ 1987 |
| o Refurbishment Cost | Post 1989 |

## MLIS Principal Issues

| | |
|---|---|
| o Firm Theoretical Model | ? |
| o Infrared & Ultraviolet Cross Sections | 3/85 |
| o Stacked Nozzle Operation | 3/87 |
| o Small (Last) Stage Performance | 3/87 |
| o Laser Propagation (Including Small Density Changes) | 3/85 |
| o Raman Conversion Efficiency | 9/84 |
| o Laser Costs | 3/87 |
| o Laser Component Reliability & Lifetimes | ~ 1990 |

## PSP Principal Issues

| | | |
|---|---|---|
| o Microwave Heating | 9/88* | |
| o $U^{++}$ Fraction | 9/88* | |
| o Effects of Sputter/Reflection on Collection | 9/83 | |
| o Drive Field Uniformity | 9/88* | |
| o Frame Blockage | 9/88 | Designs 9/86 |
| o Sputtering Due to Unbaffled Tails | 9/88 | |
| o Refurbishment Costs | Post 1989 | |

*Performance with 4 Meter Solenoid

Considering the limited resources expected to be available to the Advanced Isotope Separation program, the number of technical uncertainties, and the lack of immediate necessity for developing additional separation capacity, we recommend a reduction in the scope of the development efforts and a focus exclusively on resolving the most pressing technical issues. This could materially delay the ultimate deployment of a potentially low cost per SWU enrichment process with similar delay in the potentially very large cost benefits. For example, in the case of the MLIS program, the DOE program managers might choose to investigate ultraviolet and infrared cross sections; for AVLIS, they might select resolution of the thermal stability problem; and for the PSP program, they might investigate the stability of a 1-meter diameter plasma.

We do not believe that the three AIS processes can be evaluated intelligently in isolation from the gas centrifuge program (GCEP or AGC). It is quite possible that the AGC program would not fare particularly well if it were subject to the same peer review process which has been so useful in bringing out the key technical issues of the AIS. It is conceivable that the AGC program could be scaled back or eliminated if one or more of the AIS technologies seem manifestly superior. In that case, we would suggest reallocating funds from the AGC to the AIS program. It is also possible that the AIS technologies would compare so unfavorably to the AGC that none of the three AIS technologies should continue to be funded. Prior to final selection, the Department should conduct appropriate economic studies to determine whether further funding of any AIS technology is warranted when its marginal benefits are compared against the advanced centrifuge technology. Furthermore, in that funding for the special (plutonium) isotope program will be nearly comparable to that of the (uranium) AIS program in FY 1983, decisions affecting uranium AIS development should not be made independently of the plutonium program.

The Study Group recommends that in developing cost information to be used for such comparisons between the various enrichment processes, all applicable costs should be included. For example, RD&D costs, an appropriate share of overhead, administrative costs and any other costs needed for meaningful and "private industry" type comparisons should be applied to Separative Work Units (SWU) costs and enriched uranium products. Because expenditures will be made over an extended time period and production deployment times are likely to vary, proper discounting approaches must be used. Insofar as possible, these costs should be developed in a manner to facilitate the best possible comparisons for both short-term and long-term strategic planning and decision making.

The Study Group notes that the uranium enrichment program of the Department returns over $1 billion in sales to the U.S. Treasury, both from foreign and domestic sales. If the U.S. is to remain competitive with foreign suppliers, it will have to look at this as a commercial business and make appropriate investments. Accordingly, we repeat the AIS Study Group's previous recommendation that the DOE:

> "ask for legislation to put the enrichment enterprise on a revolving fund basis so that the operating costs will not require annual budgeting and appropriations as a part of the regular Federal budget. It would be far better if the enterprise were made an entirely independent self-financing agency (like TVA), so that the R&D and capital addition costs could be administered independent of unrelated Federal budget constraints."

In conclusion, the Study Group emphasizes that there are many factors other than technical readiness which should be taken into account prior to a decision to develop an AIS process. The specific conclusions and recommendations of the Panel are summarized as items 1.1 and 1.2, beginning on Page 1 of the Executive Summary.

## APPENDIX A
## CHARTER LETTER

THE DEPUTY SECRETARY OF ENERGY
WASHINGTON, D.C. 20585

March 19, 1982

Mr. Louis H. Roddis
Chairman
Energy Research Advisory Board
110 Broad Street
Charleston, S.C.  29401

Dear Lou:

When the Energy Research Advisory Board (ERAB) reviewed the Advanced Isotope Separation (AIS) processes in 1980, one of the recommendations was, "...to reduce the number of competing parallel processes as rapidly as possible, that is, as soon as one of the processes successfully meets the commercialization parameters of full scale development". The report further indicated that, in any case, this decision should occur by mid-FY 1983.

As you know, the Department is presently scheduled to select one of these processes for further demonstration in April of this year. The advice of ERAB on this matter would be of great value to the Department in making this critical decision. Therefore, I request ERAB make a brief reexamination of the technical status of the AIS processes and provide me with their observation and judgment as they relate to implementing a process decision at this time.

I would appreciate your recommendations as early in April as possible, so that they can be given full consideration by the Department.

Sincerely,

Ken

W. Kenneth Davis

## APPENDIX B

## 1980 ERAB STUDY GROUP RECOMMENDATIONS

(With 1982 Study Group Comments)

1.1 "We recommend that the AIS program office further identify the key technical uncertainties of the various programs, thereby establishing the basis for near-term R&D leading to a decision whether and when to proceed with full-scale development. An objective of the program office should be to reduce the number of competing parallel processes as rapidly as possible, that is, as soon as one of the processes successfully meets the commercialization parameters of full-scale development. In any case, this decision should occur by mid-FY83.....the programs should reorganize their research activities somewhat to concentrate R&D on their key technical uncertainties.....the proposed FY81 level (approximately $80 million/year in real dollars) seems appropriate."

o DOE has taken positive action to identify key technical uncertainties through the work of the Process Evaluation Board, and through the evaluation being carried out by Union Carbide Corporation-Nuclear Division. The use of the Multi-Variable Sensitivity Study in conjunction with a peer review process has, we believe, been quite effective.

o The Department is now considering the selection of one process for further development. The timing of the decision in mid-FY 1982 is, at least in part, due to the fact that the proposed FY 1983 budget is not around $80 million, but somewhat less than $35 million, as shown below:

| | FY 80 Actual | FY 81 Actual | FY 82 Appropriation | FY 83 Request |
|---|---|---|---|---|
| Dollars in Millions | $54.7 | $ 79.8 | $85.7 | $34.2 |

o It appears to the Study Group that while some attention has been given to concentrating on the key technical uncertainties, much more can, and should, be done in this area. The proposed FY 1983 budget would force the program to this approach, should more than one process be continued.

1.2 (a) "We believe that a stronger AVLIS program would result from a consolidation of the LLNL and JNAI teams, leading to a more competitive AVLIS process. Hence, we recommend that DOE attempt to negotiate with JNAI to form a single, integrated, government-funded AVLIS program with appropriate elements of LLNL, JNAI and UCCND. We further recommend that JNAI be designated as lead laboratory in this program."

o DOE attempts to negotiate a single, integrated AVLIS program were unsuccessful.

1.2 (b) "The JNAI proposal to DOE should be rejected in its present form."

o JNAI-DOE negotiations were unsuccessful, and the Department does not now support AVLIS development work at JNAI.

1.3 (a) "Continue with the first 2.2 million SWU increment of the gas centrifuge program."

o The Department continues to support this increment of the program.

1.3 (b) "Continue the Advanced Gas Centrifuge development program, with high priority."

o The Study Group believes that the Department continues to support this program at a reasonably high priority.

1.4 "We recommend that the AIS program treat as a central design problem the development of criteria, designs, and procedures which would minimize the risks of proliferation as the AIS processes mature. Ideally, development of AIS should not significantly increase the risk of proliferation."

o While the Department is obviously concerned with minimizing the risks of proliferation, we do not see evidence that it is being treated as a central design problem in the AIS program. However, based on briefings to the Study Group, we do not believe that the development of AIS will appreciably increase the risk of proliferation above that existing from the world-wide spread of early centrifuge technology. It appears that the three processes are about equal in this regard."

1.5 "For many years, the enrichment enterprise has been operated to the extent possible as an independent business, and costs of AIS R&D are included in the enterprise's financial plan. The Panel recommends that, to facilitate the making of long-term business decisions, all of the advanced uranium enrichment research and development be under the same overall DOE management organization, either in Resource Applications or any independent administrative cost center which is established. Current plans are to ask for legislation to put the enrichment enterprise on a revolving fund basis so that operating costs will not require annual budgeting and appropriation as part of the regular Federal budget. It would be far better if the enterprise were made an entirely independent self-financing agency (like TVA) so that the R&D and capital addition costs could be administered independent of unrelated Federal budget constraints."

o The Department has carried out a reorganization which placed all advanced uranium enrichment R&D under the same management organization--the Office of Uranium Enrichment and Assessment.

o The enrichment enterprise has not been put on a revolving fund basis.

o The Department has not proposed to make the enrichment enterprise an independent self-financing agency. The Study Group again makes this recommendation in the belief that it is the only way the enterprise can remain competitive.

1.6 "We recommend that periodic assessment of other isotope separation methods be continued, giving some attention to new ideas and new technology."

o The Department continues to carry out such assessments.

## APPENDIX C
## MEMBERSHIP LIST

### Advanced Isotope Separation Study Group

Louis H. Roddis, Jr., Chairman
Consulting Engineer
110 Broad Street
Charleston, S.C. 29401

Dayton Clewell
Senior Vice President (Retired)
Mobil Oil Corporation
34 Driftway Lane
Darien, CT 06820

Thomas B. Cochran
Natural Resources Defense Council
1725 I Street, NW., Suite 600
Washington, DC 20006

Richard L. Garwin
IBM
Thomas J. Watson Research Center
P.O. Box 218 - Yorktown Heights
New York, NY 10598

Edward T. Gerry
President
W. J. Schafer Associates, Inc.
1901 N. Fort Myer Drive, Suite 800
Arlington, VA 22209

William Happer
Department of Physics
Princeton University
Princeton, NJ 08540

Henry K. Hebeler
President
Boeing Aerospace Company
P.O. Box 3999
Seattle, WA 98124

Gordon O. Moe
Executive Vice President
Pacific Sierra Research Corp
1515 Wilson Boulevard
Arlington, VA 22209

Richard Osgood
Columbia University
538 W. 120th Street
Pupin Box 31
New York, NY 10027

Paul R. Vanstrum
Vice President
Nuclear Division
Union Carbide Corporation
P.O. Box Y
Oak Ridge, TN 37830

Charles E. Cathey
Executive Secretary
Room 3G-092, Forrestal Bldg
1000 Independence Avenue, SW.
Washington, DC 20585
(202)252-8933

## APPENDIX D

## BIBLIOGRAPHY

1. Report of the Energy Research Advisory Board Study Group on Advanced Isotope Separation; 11/26/80 - Unclassified.

2. Engineering Studies, Technical Evaluations, and Economic Assessments for AIS Process Selection; K/AIS 133; 3/31/82 - S/RD.

3. Appendix A - Flow Characteristics in the Irradiation Zone and Appendix B - Density Perturbations due to Heating by the Laser Beams; AP-DO-82:40; 3/26/82 - S/RD.

4. Direct Measurements of Infrared Absorption Cross Sections for Molecular Laser Isotope Separation; AP-DO-82:38; 3/26/82 - S/RD.

5. MLIS Process Model Status Report; AP-DO-82:37; 3/26/82 - S/RD.

6. Los Alamos Briefing on MLIS to the AIS Study Group; AP-DO-82:36; 3/26/82 - S/RD.

7. PSP Program Review; TRWA-97056-4433; 3/31/82 - S/RD.

8. Summary of MLIS System Evaluation and Optimization Study; CDC LIS CP-64; 2/26/82 - S/RD.

9. AIS Program Review for ERAB/AIS Study Group; CLYA 82-66; 3/31/82 - S/RD.

10. Briefing to the AIS Study Group; Y/DY-104; 3/31/82 - Unclassified.

11. Paper (Position) on Laser Beam Propagation through the Irradiation Zone; AP-DO-82:39; 3/31/82 - Unclassified.

12. PEB Presentation to ERAB; 3/31/82 - Unclassified.

# APPENDIX E

## CONFLICT OF INTEREST STATEMENT

Members of the Advanced Isotope Separation Study Group of the Energy Research Advisory Board serve without compensation (as does the ERAB itself) and are not considered Government employees. They, therefore, do not fall under normal provisions of the conflict of interest statutes.

It is, however, the practice of the Energy Research Advisory Board to consider possible interest conflict that might exist in members of the study groups. It follows that this practice should also apply to the Advanced Isotope Separation Study Group. Set forth below is the involvement in the specific area of advanced isotope separation of each member of the AIS Study Group.

Louis H. Roddis - Has consulted with Exxon R&E Co. and LASL on other matters than isotope separation.
- Was member of Isotope Separation Review for Executive Office of the President previously.

Dayton Clewell - No involvement

Thomas B. Cochran - No involvement. Has taken public positions in opposition to plutonium isotope separation of commercial nuclear fuels.

Richard L. Garwin - Consultant to Los Alamos Scientific Laboratory Separation Program and has publicly supported the MLIS approach.
- Consultant (inactive) to Exxon Nuclear on proliferation aspects of isotope separation.

Edward T. Gerry - Formerly with AVCO, on of the members of Jersey Isotopes. Member of previous (1978) AIS review group.

William Happer - No involvement

Henry K. Hebeler - Past President of Boeing Engineering and Construction Company, which has a division which manufactures centrifuges for uranium enrichment, but not now directly involved in that portion of the company.

Gordon O. Moe - Secretary of previous review panel while in Executive Office of the President.

Richard Osgood - Worked in 1977 on MIT project to develop a 16-micron laser for LASL .

Paul R. Vanstrum - Officer of that section of the Union Carbide Corporation which is directly concerned in the development of the analysis of Uranium Isotope Separation. The entire operations are performed for Federal Government in Government facilities.

# REPORT
# OF THE
# ENERGY RESEARCH ADVISORY BOARD
# STUDY GROUP
# ON
# ADVANCED ISOTOPE SEPARATION

NOVEMBER 1980

Department of Energy
Washington, D.C. 20585

NOV 26 1980

The Honorable Charles W. Duncan
Secretary of Energy
US Department of Energy
Washington, D.C. 20585

Dear Mr. Secretary:

I am pleased to transmit to you the report of the Advanced Isotope Separation (AIS) Study Group of the Energy Research Advisory Board. The AIS review was requested by the Director of Energy Research on May 1, 1980, and was completed on October 10, 1980. The report was reviewed and endorsed by the Board at its meeting on November 6, 1980. As part of its review, the Board heard public testimony from several sources and considered a number of written responses received after the draft report was made available to the public on October 16. The Study Group modified its report in response to comments made by the Board.

The Study Group, under the chairmanship of Louis Roddis, has accomplished an in-depth review of the complex technical program in a very short time. Briefly, they conclude that the Department's strategy of selecting one of the three competing AIS technologies for engineering development as soon as feasible is correct, but that the Department is optimistic in expecting a reasonable choice to be possible by mid-FY 82. They recommend moving the decision date to mid-FY 83, and organizing the programs to concentrate on key technical uncertainties (which they identify). The Study Group also recommends against funding at this time the Jersey Nuclear Avco Isotopes (JNAI) proposal which was presented to the DOE. They further find, however, the JNAI work to be critical in developing atomic vapor laser isotope separation as one of the three major competing technologies; thus, they recommend that JNAI become the lead laboratory in a single, unified, government-funded research program for that technology.

I trust that these findings and recommendations will be of use to the Department in formulating further AIS policy.

Sincerely,

Solomon J. Buchsbaum
Chairman
Energy Research Advisory Board

Department of Energy
Washington, D.C. 20585

OCT 30 1980

Solomon J. Buchsbaum
Executive Vice President
Customer Systems
Bell Laboratories
Crawford Corner Road
Holmdel, NJ 07733

Dear Sol:

Attached is the draft report of the ERAB Advanced Isotope Separation Study Group Report, which I am forwarding to you so that it may be distributed prior to the 6-7 November ERAB meeting. This draft was cleared by DOE security today as a fully unclassified document.

Sincerely,

Louis H. Roddis
Chairman
AIS Study Group

## PANEL MEMBERS

Louis H. Roddis, Chairman
Consulting Engineer
110 Broad Street
Charleston, S.C. 29401

Dayton Clewell
34 Driftway Lane
Darien, CT 06820

Thomas B. Cochran
Natural Resources Defense Council
1725 I Street, N.W.
Suite 600
Washington, D.C. 20006

W. Kenneth Davis
Vice President
Bechtel Power Corporation
P.O. Box 3965
San Francisco, CA 94119

Richard L. Garwin
IBM
Thomas J. Watson Research Center
P.O. Box 218 - Yorktown Heights
New York, NY 10598

Edward T. Gerry
President
W.J. Schafer Associates, Inc.
1901 N. Fort Myer Drive
Suite 800
Arlington, VA 22209

William Happer
Department of Physics
Princeton University
Princeton, NJ 08540

Henry K. Hebeler
President
Boeing Aerospace Company
P.O. Box 3999
Seattle, WA 98124

Gordon O. Moe
Executive Vice President
Pacific Sierra Research Corp.
1515 Wilson Boulevard
Arlington, VA 22209

Richard Osgood
MIT
Lincoln Laboratory
Wood Street
Lexington, MA 02173

Paul R. Vanstrum
Vice President
Nuclear Division
Union Carbide Corporation
P.O. Box Y
Oak Ridge, TN 37830

Thomas H. Johnson
Executive Secretary
Science Research Laboratory
US Military Academy
West Point, NY 10996

## 1. EXECUTIVE SUMMARY

The Panel reviewed Advanced Isotope Separation (AIS) technology and Advanced Gas Centrifuge (AGC) programs in the context of potential needs and costs for uranium enrichment. The benefit of a successful AIS or AGC program would be a substantial reduction in enrichment costs below those of current centrifuge plants or below the power cost alone for gaseous diffusion plants. This report attempts to provide firm guidance for the next 2-3 years, at which time a further evaluation should guide decisions in regard to enrichment supply and development choices.

On the basis of our perception of the long term economic benefits of a successful AIS development, we support the continued pursuit of this option. In the interim, major requirements for enrichment must be satisfied. We assume that DOE will develop a firm funding plan for gaseous diffusion operations and power contracting to assure that the necessary supply of power will be available to meet the separative work commitments of the U.S. enrichment enterprise.

1.1 We recommend that the AIS program office further identify the key technical uncertainties of the various programs, thereby establishing the basis for near-term R&D leading to a decision whether and when to proceed with full-scale development. An objective of the program office should be to reduce the number of competing parallel processes as rapidly as possible, that is, as soon as one of the processes successfully meets the commercialization parameters of full-scale development. In any case, this decision should occur by mid-FY83 ... the programs should reorganize their research activities somewhat to concentrate R&D on their key technical uncertainties ... the proposed FY81 level (approximately $80 million/year in real dollars) seems appropriate.

1.2 (a) We believe that a stronger AVLIS program would result from a consolidation of the LLNL and JNAI teams, leading to a more competitive AVLIS process. Hence, we recommend that DOE attempt to negotiate with JNAI to form a single, integrated, government-funded AVLIS program with appropriate elements of LLNL, JNAI and UCC-ND. We further recommend that JNAI be designated as lead laboratory in this program.

(b) The JNAI proposal to DOE should be rejected in its present form.

1.3 We recommend that the DOE:

(a) Continue with the first 2.2 million SWU increment of the gas centrifuge program.

(b) Continue the Advanced Gas Centrifuge development program, with high priority.

1.4 We recommend that the AIS program treat as a central design problem the development of criteria, designs, and procedures which would minimize the risks of proliferation as the AIS processes mature. Ideally, development of AIS should not significantly increase the risk of proliferation.

1.5 For many years, the enrichment enterprise has been operated to the extent possible as an independent business, and costs of AIS R&D are included in the enterprise's financial plan. The Panel recommends that, to facilitate the making of long-term business decisions, all of the advanced uranium enrichment research and development be under the same overall DOE management organization, either in Resource Applications or any independent administrative cost center which is established. Current plans are to ask for legislation to put the enrichment enterprise on a revolving fund basis so that operating costs will not require annual budgeting and appropriation as part of the regular Federal budget. It would be far better if the enterprise were made an entirely independent self-financing agency (like TVA) so that the R&D and capital addition costs could be administered independent of unrelated federal budget constraints.

1.6 We recommend that periodic assessment of other isotope separation methods be continued, giving some attention to new ideas and new technology.

## 2. INTRODUCTION

On May 1, 1980, Dr. Edward A. Frieman, Director of Energy Research, requested (see Appendix A) that the Energy Research Advisory Board (ERAB) review the Department of Energy programs in Advanced Isotope Separation (AIS) techniques and the role of Jersey Nuclear AVCO Isotopes in that program. Specifically, ERAB was requested to review the AVLIS, PSP, MLIS and JNAI (AVLIS) processes with respect to:

- Overall Advanced Isotope Separation Program Strategy
- Current technology state of the art
- Future risks, benefits and costs associated with implementation of a particular AIS technology.

This report is in response to Dr. Frieman's request. The AIS program has received many reviews in the past, but technical progress since the 1978 review and the proposal to the government by JNAI have made this review desirable. The panel was later asked by Dr. Frieman to review the Advanced Gas Centrifuge program as part of overall enrichment technology development.

To carry out the review, the ERAB appointed an ad hoc Advanced Isotope Review Panel. The panel heard extensive presentations from Dr. Neil Goldenberg, Acting Director, Office of Advanced Nuclear Systems and Projects, Nuclear Energy, and his staff, from Dr. Wm. Voigt, Director, Office of Uranium Resources and Enrichment, Resource Applications, and his staff, and from numerous scientists and engineers in the program. The Panel heard nine days of briefings at the sites of participating organizations (see Appendix D), and met in Washington, D.C. to prepare its conclusions and reports.

Both at Headquarters and in the field (including JNAI), the Panel received outstanding cooperation and assistance in their understanding of the problems and promise of the various AIS and AGC technologies. We also received adequate briefings on the present gaseous diffusion and gaseous centrifuge technology and operations for an understanding of the entire enrichment enterprise. Because much of the detailed technology is highly classified (and in the case of JNAI also proprietary), this report has had to eliminate some technical detail. This in no way affects the outcome of the Panel's recommendations. We believe the information in this report will enable the reader to judge these recommendations adequately.

The issues involved in a judicious analysis of AIS and AGC technology and requirements are complex and far reaching. (References 35-37) Not only must one evaluate the technical status and prospects of physics and engineering; but to judge the urgency for development of these technologies, one must also consider the broader picture of US requirements for uranium enrichment, and how, variously, these requirements might be satisfied.

Various alternative means for satisfying production requirements are considered in detail in Appendix B.

U.S. requirements for enriched uranium are quite uncertain because of the uncertain growth in U.S. nuclear power and the share of the world market expected to be supplied by the U.S. Current contracts with DOE involve commitment to supply enriched uranium for 304 GWe of nuclear power in 2000 AD, but some of the reactors covered by these contracts will not be built. A range of requirements to support from 250-350 GWe of nuclear power by 2000 AD appears to be a reasonable planning base for current decisions on uranium enrichment.

The gas centrifuge is the best technology in hand today to expand U.S. capacity beyond that available from the gaseous diffusion complex. The centrifuge plant under construction at Portsmouth, Ohio, enabled the opening of order books for U.S. sales of enriching service, and at least 2.2 million SWUs are needed to meet current U.S. contract commitments. Current plans are to build an 8.8 million SWU plant on a schedule adjusted with time to be consistent with actual enrichment demands, including maintaining a level of inventory that provides a high level of confidence in ability to deliver. The AIS processes are expected to play an important role in the 1990s. This role will be affected by a number of factors including, most importantly, the level of requirements to support nuclear power, the cost of SWUs for AIS relative to GD and GC, the cost of uranium feed as it affects the optimum tails concentration, and the time at which the new AIS and AGC technologies become available. Table 3.2 and Figure 3.3. graphically summarize this situation.

It is apparent that both the centrifuge and AIS technologies are important elements of an economically sound and assured supply of U.S. enrichment services. The centrifuge is unique in the near term; its role in the longer term will be influenced by progress in the AIS technologies.

Because of the potential for continuing differential escalation in the cost of power, both advanced gas centrifuge and AIS processes appear to be attractive candidates eventually to replace the U.S. gaseous diffusion complex. If the AIS processes can achieve their full potential in terms of low-cost SWUs, multibillion-dollar savings could be realized by the year 2000. The remainder of the report presents the findings of the Panel with regard to these issues.

## 3. STATUS, RISKS, BENEFITS, COSTS

### 3.1 State-of-the-Art-Summary

Of these processes evaluated, the advanced gaseous centrifuge is closest to development. The MLIS process clearly benefits from the substantial technology base and production infrastructure which already exist for handling $UF_6$. System reliability for atomic vapor handling remains a major technical issue for the other processes. All three of the laser processes appear to have found workable lasers of proper wavelengths capable of scaling to appropriate powers and repetition rates, with the JNAI hardware being most advanced and the MLIS least tested. JNAI has tested prototypical componentry of many critical elements of their system; very little prototype scale hardware has been tested for the other AIS processes. The PSP benefits from use of better developed less complex components, but resolution of the physics scaling awaits the results of the 1-m diameter scale demonstration. A more detailed description of the AIS processes evaluated here appears in Appendix A.

The current DOE plan for AIS calls for process selection in 1982 with parallel process development through that time. The development module based on the selected process is scheduled to be operating in 1986 and the earliest production capability could be brought on in 1990 or 1991. The most optimistic schedules for any of the AIS processes based on selection now and concurrent development would lead to production no earlier than 1988.

None of the AIS processes has produced more than a few grams of enriched material in integrated experiments to date. None of these experiments has yet been carried out under full combined process conditions. However, many kilograms of uranium or $UF_6$ have been handled, without separative work, in the laboratory versions of the proposed plant modules. The production of significant quantities of enriched product will not occur under the present plan until a development module is operating in 1986. Prototypes of the advanced gas centrifuge will not be available until 1982, but large amounts of enriched uranium have been produced in units very similar to the planned Set IV machines.

Research is also being conducted on the possible application of LIS methods to plutonium. Such methods could be used to reduce the 240-Isotope content of N-reactor plutonium, some 4 tons of which now exist.

## 3.2 Other Isotope Separation Methods

Over the past forty years, a large number of other isotope separation methods have been studied, and an even larger number have been proposed. There is, in fact, a continuing flow of ideas on new methods or modified versions of old methods which are offered as having potential for application in uranium enrichment. It should be asked whether or not any of these other methods need be taken into account in developing the proper strategy. The Panel has relied on a recent comprehensive DOE assessment of methods of uranium isotope separation (References 17, 18 and 27) in reaching the conclusion that the four processes which have been examined in detail have the greatest potential for low-cost separative work and, together with gaseous diffusion and gas centrifuge, provide a sufficiently broad base for planning advanced isotope separation programs. Such periodic assessments of these enrichment approaches as exemplified by References 17, 18 and 27 should continue. Attention should be given to proposed new ideas and new technology that might be applied to reduce the cost of uranium isotope separation. At the same time, care should be taken to avoid excessive commitments of funds or resources to methods which do not have clear or substantial economic advantage over the current production processes. For example, the French chemical exchange process, although potentially competitive with gaseous diffusion, does not appear to promise the economic or other advantages of either the centrifuge or AIS processes.

## 3.3 Programmatic Risk

### AGC

No substantial programmatic risks were observed in the GCEP program, and the risks associated with Advanced Gas Centrifuge development appeared minimal with regard to SET IV and only moderate for future SET's. Actual performance of gas centrifuge has been better than projected in the past so that centrifuge performance projections by the DOE could be conservative.

### AIS

The AIS processes are still in the technology development stage and, thus, long-term programmatic risk is difficult to assess. Each of the AIS process development projects contains one or more key technical issues which must be resolved prior to a production demonstration decision; some of these issues are highlighted in Section 4. In the laser processes, most of the issues are related to laser reliability, optical propagation, beam-train design and, in one case, extraction design. In the plasma separation process, issues related to energy selectivity and production throughput scaling clearly need resolution. The currently planned AIS development program does not appear to allow sufficient time to resolve these key technical issues prior to selecting a concept for engineering development and production scale-up. Thus the planned FY82 selection date seems to involve high program risk; a selection date in FY83 could reduce the risk substantially.

### 3.4 Nuclear Weapons Proliferation Implications

The nuclear weapons proliferation implications of advanced isotope processes have been reviewed by DOE and others. (References 28-34 inclusive)

In assessing the proliferation risks of AIS processes, three technical paths, ranked in order of importance, must be considered:

- the process will be developed independently by another nation for the production of weapons material;
- the process designed for LEU production will be altered to produce HEU; and
- LEU will be diverted from the plant to subsequent production of HEU.

In each case, the central question is whether the proliferation risks will change (and in what direction) with the development and deployment of these new technologies; therefore, the proliferation risks of each AIS process must be compared against alternatives currently available -- gaseous diffusion and gas centrifuge plants. Likewise, consideration must be given to the fact that AIS technologies are being developed independently in other countries.

All AIS processes involve the successful integration of several sophisticated technologies and, as such, none presents a significant risk in terms of development from the ground up by small non-government organizations (i.e., individuals or terrorist organizations).

All AIS processes are at early stages of development (i.e., research programs) and have produced only gram quantities of LEU, whereas the gas centrifuge technology has been deployed commercially. The early stage of AIS development, together with the inherent high-technology aspects of AIS processes, make them unlikely avenues for proliferation now by any except advanced countries. Thus, the remainder of this discussion assumes the AIS processes have been succesfully developed and deployed as mature industries.

Independent process development by another nation could follow two paths. First, the country could develop the process independently by initiating its own research effort and technological development program; or, alternatively, the country could obtain access to the technology (e.g., engineering plans) and purchase the needed hardware on the commercial market. The first alternative probably more nearly describes the historic development of gaseous diffusion technology by the United Kingdom and France, and perhaps of the aerodynamic process by South Africa. The second alternative is currently being attempted by Pakistan in developing a gas centrifuge plant.

All of the AIS processes appear today to be substantially more difficult to develop from scratch than the gas centrifuge and, consequently they are not now the preferred (proliferation) alternative and do not add significantly to the "baseline" risk. If and when the laser processes become publicly well understood, they may still be less attractive than the gas centrifuge process for dedicated HEU production in small amounts because of their sophisticated technologies. However, the technologies and hardware requirement of the PSP are more established than those used in laser processes, and the smaller size of an economical PSP module may make PSP more of a proliferation hazard.

Whether any of these differences between AIS and gas centrifuge will be significant in the future depends on a number of factors, e.g., developments in laser technology and their deployment. These are difficult to predict and, consequently, these assessments must be subject to continued scrutiny and declassification actions should not be taken lightly. The projected costs for AIS suggest that by the 1990s one or more of these processes may become the favored process for proliferation, particularly if there is access to the technology on an unclassified or otherwise available basis.

All AIS processes designed for LEU production seem capable of modification to HEU production. Since the processes are optimized for LEU, the alterations including, for example, reduced feed flows cause a reduction in plant capacity (i.e., SWU/yr). However, this would not be a significant penalty under some diversion scenarios because a weapons program needs such small amounts of separative work compared to supplying LEU to large power reactors.

All AIS processes and gas centrifuges, however, in theory could be designed (and safeguarded by inspection) -- in some cases without significant penalty to plant performance or economics -- to make covert conversion of an existing AIS facility for LEU to HEU production (while under safeguard inspection) exceedingly difficult. A gas centrifuge facility which was not under safeguards control would be simpler to convert covertly and, thus represents a higher proliferation risk. AIS plants are expected to have very few equipment modules compared to the thousands of centrifuges.

All AIS processes have one advantage over gaseous diffusion (but not gas centrifuge) plants with regard to diversion of LEU for subsequent production of HEU, namely, they have lower in-process inventories, which could lead to better material accounting and control. However, because designs and operating procedures are not yet focused it is difficult to judge the relative merits of the AIS processes with regard to LEU diversion, or to compare them against the existing diffusion or centrifuge concepts.

While steps could be taken in all AIS processes to provide signficant deterrence to diversion of material or separative work, no evidence was presented to indicate that the program is giving serious attention to these matters at this time.

## 3.5 Power Limitation Problems

For the next ten years essentially all the capability of the U.S. to provide enriched uranium will depend on the gaseous diffusion plants and the availability of power to operate them. Beyond 1990 the dependence on power will be determined by the extent of deployment of the gas centrifuge and AIS, and it is apparent that as currently planned it is likely to be the mid- to late 1990s before the AIS technologies can both add necessary new capacity and at the same time replace existing capacity. Current electric power contracts are shown in Figure 3.1 extending to 1992. Whether the energy will actually be made available cannot be certain. Severe energy curtailments at the diffusion plant because of budgets or energy shortages have been mutually negotiated with the suppliers in the past, and this could well occur again.

It has been convenient and cost effective to use the diffusion plants for seasonal load leveling, particularly since sustained high levels of SWU production have not been needed in the last decade. In the 1985-1995 period, however, this mode of operation may not be acceptable if production needs are to be met particularly if AGC and AIS progress is less than anticipated. Operating with daily, weekly and annual electric capacity cyclic swing should continue to be studied as a realistic operating mode to move towards maximum possible output and reduced cost per SWU. Excessive energy curtailments in reality or in prospect would lead to default on uranium enrichment contracts or to the deployment of gas centrifuge or AIS, with their low energy requirements, on a crash basis. Careful planning now both to assure power availability as well as to have strongly supported centrifuge construction and advanced separation efforts are sound options to maintain the position of a reliable supplier of enrichment service.

## 3.6 Economic Considerations

### Introduction

Whatever the selling price of SWUs and whether the producer is government or private industry, the nation is richer if the cost of SWUs is reduced. In the late 1980s U.S. sales are expected to be about 2.5 billion dollars per year in 1980 dollars, and during the 1990s this is expected to increase to an even higher level. Reductions in cost of production and, in particular, reductions in cost of expansion in capacity can lead to large savings in the costs of SWUs.

Cost, to be relevant, must be marginal cost. For example, if capacity is not to be expanded, only out-of-pocket costs for gaseous diffusion can be considered in making process comparisons. Furthermore, a consistent costing rule should be followed; e.g., internal rates of return should be calculated using all future costs (including R&D). In addition, it is important in forecasting to take into account any differential escalation that might be expected with power costs in the future, since this is an important cost element with the gaseous diffusion process.

Taking all these concerns into account and evaluating the potential savings to be realized from choosing the proper strategy in planning the enrichment industry, it can be expected that use of new technology--the gas centrifuge and AIS--on a timely basis can lower total enterprise costs from 1980 to 2000 by as much as several billion dollars. In addition, more reasonable levels of feed required and power used can be assured. Yearly adjustments of the strategy would maximize the savings realized.

### Comparison of AIS Projection and Other Enrichment Process Costs/Projections

In planning the total enrichment enterprise for the next 20 to 30 years, it is, of course, necessary to consider economic comparisons of all available and potential processes. Such comparisons are extremely difficult, given the fact that the technologies are fundamentally different and at different stages of development/commercialization. In the final analysis, there is no rigorous way to treat today's actual gaseous diffusion production costs and projected future costs of a new technology still undergoing development comparably, so the task becomes one of providing balanced comparisons which are at least qualitatively meaningful.

The attached Table 3.2 shows some of the key cost and economic factors for the various uranium enrichment processes starting with costs for the existing GDP plants and including a new "free-standing" GDP, gas centrifuge plants at various levels of construction or development, as well as the various AIS processes. The costs range from fairly well known numbers on the left to fairly speculative costs based largely on estimates of the developers for the AIS processes. While the method of analysis is otherwise reasonably consistent, the probable accuracy decreases for the AIS processes. One minimum requirement of such a comparison is that consistent financial "ground rules", e.g., amortization periods, discount rates, etc., be used. Utilizing a fairly standard set of such rules*, the projections shown were presented by program participants to the committee.

One general conclusion drawn from Table 3.2 is that operating costs, excluding the cost of electric power, are about the same for all of the processes and do not provide a basis for choice among the processes.

Similarly, except for the high cost of electric power for the GDP (more than the expected total costs for all other processes except GCEP), the cost of electric power is low for all, and again offers little basis for discrimination between the alternative processes.

Clearly, the crucial comparison (aside from technical feasibility and reliability) is that related to unit capital costs as reflected in the dollars (1980) per annual separative work unit ($/ASWU). Unit capital costs for both new GDP and GCEP are high, leading to uranium enrichment costs higher than present sale prices. There is considerable confidence, however, that the AGC can, over a 15-year period, lead to unit capital costs about 50 percent those of current GCEP.

The AIS processes hold the prospect of further unit capital cost reduction of as much as another factor of 4 (according to the developers of the processes), although at this stage of development it would seem prudent to double these costs and consider AIS as providing a margin of $100 to $150/ASU-capacity as compared with AGC on the same time scale. Larger margins may turn out to be real but should not be counted on now.

Thus, the key issue is the determination of the validity of the early cost estimates for the AIS processes (as well as their technical feasibility and performance). While the development of the AGC seems more straightforward and thus inspires more confidence, it is essential to validate cost levels for it as well. While the projections are useful, one problem with the approach reflected in Table 3.2, aside from the fundamental inability to reconcile differences in technology status and type, is the absence of any timing relationships among the various options and potential options. The diffusion plants are presently available for full operation, and their capital cost is sunk; furthermore, firm power contracts exist for 7160 MW through 1992; the Portsmouth centrifuge plant is under construction, capital is being expended, and operations will scale to full capacity over the next 14 years, with the opportunity to incorporate advanced technology during the last 6 years. Finally, the AIS processes are being actively readied for full-scale systems testing and demonstration during the next 5 to 7 years, with the probability of being ready for commercial operation in the early-to-mid-90's time frame.

---

*Ten-year amortization at 10% p.a. with interest during construction (at 10% p.a.) capitalized.

In Figure 3.3. the committee has tried to illustrate the interrelations of these options in terms of timing and cost. In constructing Figure 3.3, the goal was approximate conceptual presentations rather than computational rigidity. That is, the curves are intended to portray "how things might look", based on what we know today; the curves do not necessarily faithfully reproduce any given set of estimates presented to the committee. Some features are:

Gaseous Diffusion. The out-of-pocket production costs are shown as $65/ASWU for the existing gaseous diffusion plants based on current power contract costs, or $88/ASWU using 35 mil power (as projected for 1990). These costs vary to some extent because of variable production levels, but primarily because of uncertainty in the differential escalation rate between energy cost and the balance of the economy. This uncertainty is magnified into considerable future cost uncertainty for gaseous diffusion because the process is so particularly energy intensive, with no significant room left to improve its energy requirements. New gaseous diffusion plants are indicated to provide enrichment at $178/SWU (35 mil power) in FY 1980 dollars; differential escalation would, of course, also drive this cost higher over the years.

GCEP. The gas centrifuge enrichment plant (GCEP) is a congressionally authorized line item construction project at Portsmouth, Ohio. Site work is well under way, but the schedule is protracted because of softness in the demand for enrichment services world-wide. For purposes of this comparison, internally consistent economic criteria were used together with actual GCEP budget numbers. Since there will be substantial GCEP expenditures through the early and mid-1980's, the curve shown gives the forward cost at any time for completing the project (8 buildings). This, of course, decreases as costs are sunk and also if advanced technology (Set IV) is incorporated. Once GCEP portions are complete and costs are sunk, the forward out-of-pocket production costs are very low.

New Gas Centrifuge Plants. Projections of average unit costs (not forward costs), including interest during construction, for new plants using advanced gas centrifuge are shown. In this case, it is assumed that the advanced gas centrifuge technology is developed approximately as targeted, and three possible outcomes in performance level were considered. If the program achieves its goals, then significant cost reductions below the GCEP cost might be in hand by the late 1980's.

New AIS Plants. Current plans call for one or more of the AIS processes to be ready for production utilization beginning sometime in the early-to-mid-1990's. For purposes of this illustration, it was assumed that the AIS represented an evolving technology and that full performance might not be realized on the first copy. Therefore, an additional factor-of-two capital cost penalty was applied to the early installations, with mature-technology cost used for later installations, to give a more realistic view of how AIS costs might evolve.

These curves illustrate the following points:

Within the immediate term (next 2 years), the only firm options for commitment to future enrichment services are gaseous diffusion, the GCEP project, and, of course, other centrifuge plants using Set III technology.

Within the near term (next 2 to 4 years), the firm option of incorporating Set IV technology in GCEP and in new centrifuge plants beginning in the late 1980's may be available if the advanced centrifuge program is adequately supported and successful. This would be a very beneficial outcome.

Within the intermediate term (next 4 to 7 years), the option of using AIS for new plants in the 1990's will become better defined, and it will be possible to project the timing/cost relationships with much greater certainty.

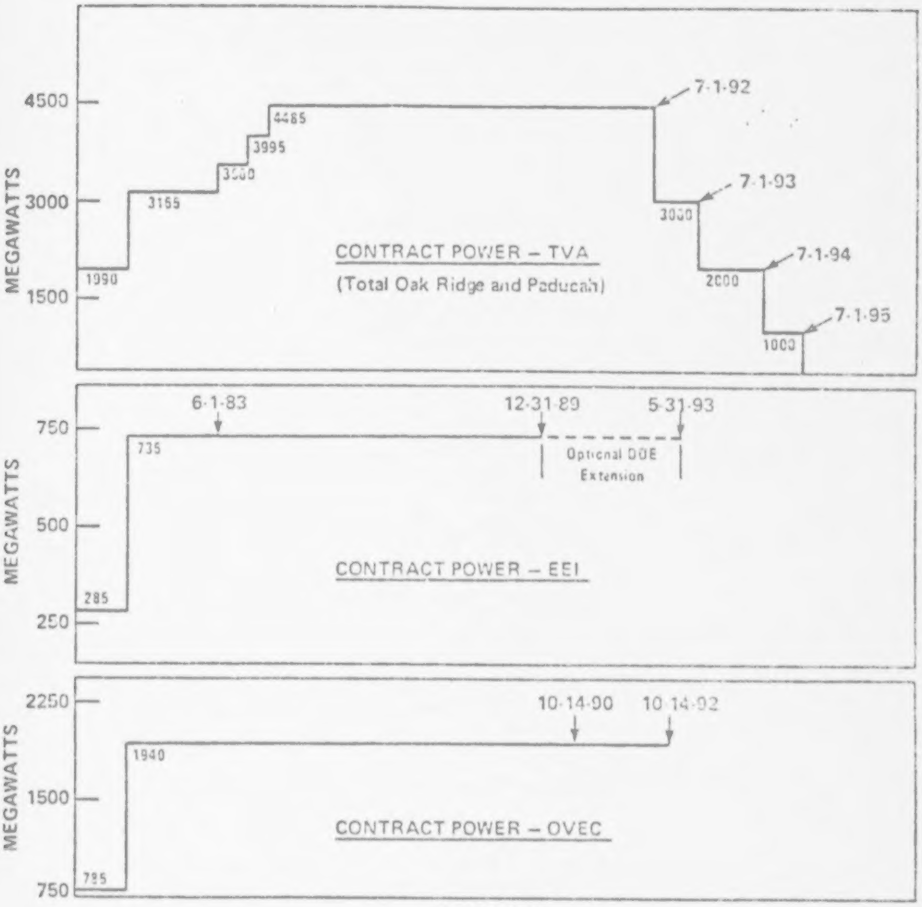
As the GCEP project is implemented during the next 14 years, the sunk-cost/available-production ratio decreases considerably. Forward costs to complete the project will become lower and lower, particularly if the advanced technology is incorporated. Once GCEP capital costs are sunk, its out-of-pocket operating costs are very low. GCEP, rather than the diffusion plants, would become the enrichment complex base, with GDP taking up the slack.

Finally, it should be noted that rather ambitious targets have been established for both the advanced gas centrifuge and AIS technologies. To achieve these targets will require a commitment and concentration of resources beyond the current status, particularly in the AIS program. The important goal is to commit to implementation a single AIS production capability whenever its costs are clearly below the forward cost of GCEP or AGC, pressing for further cost reduction after the AIS plant is operational. If energy costs continue to escalate at a greater rate than construction and labor costs, then gaseous diffusion capacity displacement by advanced centrifuge and/or AIS plants would be very profitable.

FIGURE 3.1

CONTRACT POWER

DWG. NO. K/G-89-2839R1
(U)



| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL MWe | | | | | | | | | | | | | | | | |
| 3000 | 5840 | 5640 | 6235 | 6670 | 7160 | 7160 | 7160 | 7160 | 7160 | 7160 | 7160 | | | | | |
| FISCAL YEAR | | | | | | | | | | | | | | | | |
| 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |

TABLE 3.2: KEY COSTS AND ECONOMIC FACTORS

| | Existing GD Plant Fully Powered CIP/CUP | New Stand-Alone GD Plant Current Tech. | Current Planned GCEP | | | New AGC Plant 1990's Tech. Set VI | AIS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | AVLIS | | MLIS | PSP |
| | | | Bldg. 1-2 Set III | Bldg. 3-8 Set IV | Full GCEP 1-8 Set IV | | JNAI | LLL | | |
| Reference Size: MASWU | | 9.3 | 2.2 | 9.9 | 13.2 | 8.8 | 10.0 | 8.61 | 8.75 | 9.35 |
| Power KWH/SWU | 2360 | 2475 | 135 | 95 | 95 | 48 | 54 | 65 | 77 | 221 |
| Investment | | | | | | | | | | |
| Unit Cap: $/ASWU | ---- | 505 | 1425 | 281 | 498 | 280 | 63 | 77 | 107 | 100 |
| Power Plant: $/ASWU[1] | ---- | 434 | 24 | 17 | 17 | 8 | 10 | 12 | 13 | 39 |
| Total: $/ASWU | | 939 | 1449 | 298 | 515 | 288 | 73 | 89 | 120 | 139 |
| Annual Cost | | | | | | | | | | |
| Power Cost: $/SWU[2] | 83 | 87 | 5 | 3 | 3 | 2 | 2 | 2 | 3 | 8 |
| Oper. Cost: $/SWU | 5 | 9 | 16 | 14 | 14 | 10 | 9 | 6 | 8 | 7 |
| Cap. Cost: $/SWU[3] | -- | 82 | 232 | 46 | 81 | 46 | 10 | 13 | 17 | 16 |
| Total: $/SWU | 88 | 178 | 253 | 63 | 98 | 58 | 21 | 21 | 28 | 31 |

All in mid-1980 constant value dollars (no escalation).
All are evaluated on comparable basis (to extent feasible).

[1] Power plant investment to serve at $850/KW for nuclear plants, 65% CF and $150/KW for switchyard, transmission, and distribution.

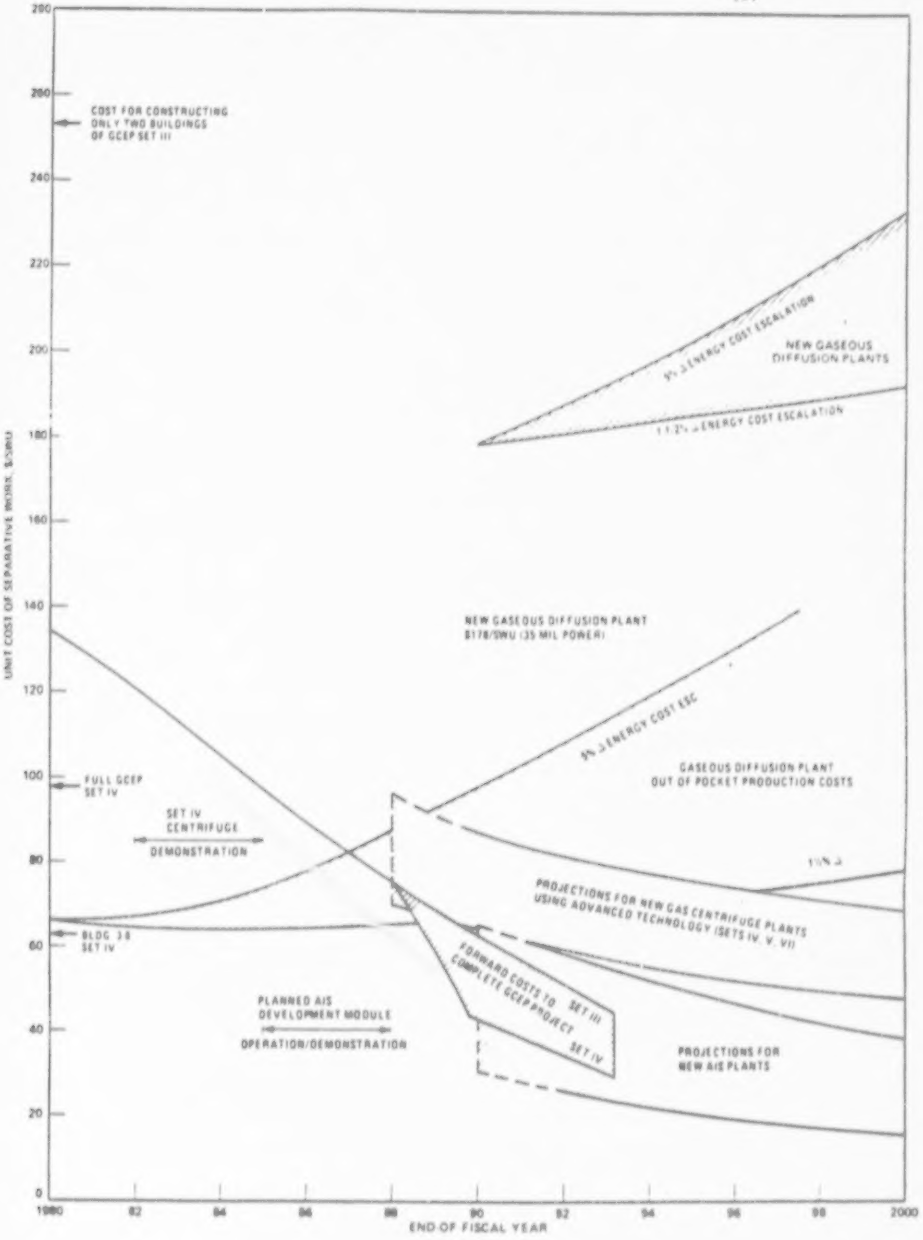
[2] At 35 mills/KW hr.

[3] At 10 yr and 10%, 16.28% p.a. on total investment (including IDC, etc. Since the various projects require different building space, auxiliaries, etc., an attempt was made to pick reasonably comparable construction periods, i.e., 5 yr for AIS, 6 yr for the full GCEP project.

Figure 3.3

TIME-COST PROJECTION FOR ENRICHMENT

DWG. NO. K/G-80-2648R2
(U)



## 4. CONCLUSIONS AND RECOMMENDATIONS

### 4.1 AIS Program

The AIS processes offer the best prospects for low-cost separative work in the 1990s of any known methods. The marginal comparison, however, is with gas centrifuge technology. Although present U.S. gas centrifuge technology is far more energy efficient than gaseous diffusion, its capital cost is very high. There is a potential $2 billion annual power cost savings benefit associated with replacing gaseous diffusion operations and reducing some gas centrifuge investment by the deployment of AIS, which provides both low power consumption and low capital cost. This benefit could result from cost savings in meeting future increases in demand, from replacement of gaseous diffusion (because total AIS costs are projected to be lower than out-of-pocket costs for gaseous diffusion), or from reduction of the U-235 content of stored tails to produce reactor-level product or normal feed, thus reducing feed costs.

On the basis of our perception of the long-term economic benefits of a successful AIS development, we support the continued pursuit of this option. However, the current projections for SWU demand to be supported by the U.S. enrichment enterprise do not justify parallel engineering development of all these approaches given the current technical uncertainties. We therefore support the current DOE strategy of parallel technical issue resolution in the near term, focussed toward a decision within a few years for engineering development and deployment of a single AIS process. In the interim, major requirements for enrichment must be satisfied. With regard to interim energy utilization, we assume that DOE will develop a firm funding plan for gaseous diffusion operations and power will be available to meet the separative work commitments of the U.S. enrichment enterprise.

Because no near-term urgency exists for additional production capacity, the primary driving force for AIS development is the potentially low cost of SWUs for possible future production requirements. Since the saving from AIS ultimately realized will depend on the time of production deployment as well as the costs achieved, and since early focus on the selected process will speed deployment and minimize research and development costs, the target date for process selection should be made as early as possible consistent with the availability of sufficient information to make possible a reasonably assured wise choice.

The Panel is persuaded that:

(a) The three AIS processes, AVLIS, MLIS and PSP, all appear technically feasible for large-scale separation and offer prospects for delivering SWU costs in the $20-40 range.

(b) All three processes have major physics or fundamental engineering questions which must be answered before a well-bracketed cost and schedule for a production plant can be obtained. Difficulties in those areas might in each case prove to be an insuperable barrier to commercialization of that particular process. Areas of key technical uncertainties identified by the Panel are:

| | |
|---|---|
| PSP | Density and throughput (physics)<br>Atomic vapor system reliability (engineering) |
| AVLIS | Optical propagation (engineering physics)<br>Laser reliability (engineering)<br>Atomic vapor system reliability (engineering) |
| MLIS | Laser performance (engineering physics)<br>Laser reliability (engineering) |

(c) Because of these uncertainties, insufficient information currently exists to make a sound estimate of the overall probability of success of any of the three processes. The superiority of any of the AIS processes over the others or over AGC is not demonstratable now. Consequently, there is now no technical basis for selection of one of the AIS processes over the others.

(d) It is highly unlikely that by mid-FY82 all three, or indeed any particular one, of the processes will have resolved its key technical uncertainties. Thus, it is unlikely that by mid-FY82 a firm technical basis for selection will exist.

We recommend that the AIS program office further identify the key technical uncertainties of the various programs, thereby establishing the basis for near-term R&D leading to a decision whether and when to proceed with full-scale development. An objective of the program office should be to reduce the number of competing parallel processes as rapidly as possible, that is, as soon as one of the processes successfully meets the commercial parameters of full-scale development. In any case, this decision should occur by mid-FY83. If at that date or earlier PSP or MLIS or AVLIS demonstrates that the key technology elements are in hand to support credible costs for a 2 million ASWU plant below then-available centrifuge product costs, that approach should proceed into a production module as quickly as is economically feasible. The competing approaches should be reduced to small-scale back-up programs.

To be prepared for an FY83 decision date, the programs should reorganize their research activities somewhat to concentrate R&D on their key technical uncertainties. For example, we note that PSP operating parameters will be adequately tested on the one-meter device. In addition, laser reliability issues for MLIS can be pursued separately from any module, as can optical propagation issues for AVLIS. With such internal reallocations, it should be possible to meet the selection date with no significant increase in the overall program budget. That is, the proposed FY81 level (approximately $80 million/year in real dollars) seems appropriate to timely process selection (development then being limited by the technology itself), and to the significance of AIS to the larger issue of enrichment demand. One exception to this limit should be a provision for each process to receive the necessary funds (typically several million dollars) during the last year before process selection, to permit the necessary full engineering studies of plant design and integration.

## 4.2 JNAI

The technical uncertainties mentioned above apply to the JNAI process as well as to the LLNL, LANSL and TRW processes. It is therefore as inappropriate to select JNAI for demonstration module development now as it would be to select any of the other processes now.

There is, however, great merit in the AVLIS work which JNAI has done, particularly in their work on engineering design and hardware development. We also find significant value in the LLNL participation in AVLIS, particularly their theoretical work and basic-process physics (spectroscopy, for example), and in the UCC-ND (Y-12) collector project done under DOE contract and coordinated with LLNL.

(a) We believe that a stronger AVLIS program would result from a consolidation of the LLNL and JNAI teams, leading to a more competitive AVLIS process. Hence, we recommend that DOE attempt to negotiate with JNAI to form a single, integrated, government-funded AVLIS program with appropriate elements of LLNL, JNAI and UCC-ND. We further recommend that JNAI be designated as lead laboratory in this program. JNAI is chosen as the lead lab because of their broader perspective and experience in the practical and business aspects of bringing such a complex technology to commercialization. Specific work should be divided among the three participants along the lines suggested above; the integration of these program elements should be accomplished within six months. The integration should be possible within or close to the planned funding envelope for AVLIS, and should not be accomplished at the expense of the MLIS or PSP programs. If such an arrangement cannot be negotiated, the AVLIS development may lose able people of proven productivity, failing to exploit the best combination of technologies; its chances of meeting the proposed decision date will be significantly reduced.

(b) The JNAI proposal to DOE should be rejected in its present form. The committee makes no comment on the specific business terms of the JNAI proposal. Such matters clearly must be negotiated by the Department. JNAI has made real technical contributions to the AVLIS concept, but the precise current or future economic value of those contributions cannot be assessed by our committee; nor the price which must be paid to obtain access to these contributions. Nor could we choose among alternative modes of managing joint technical participation.

## 4.3 Gas Centrifuge

The gas centrifuge is the lowest cost uranium enrichment process available today for new plants. Construction of the GCEP at Portsmouth (authorized in 1978 and now under way) enables U.S. order books for uranium enrichment to be reopened to new orders and helps insure our position as a reliable supplier of enrichment services. One attraction of the centrifuge process is that it uses less than five percent of the power of a gaseous diffusion plant of comparable size, and therefore its selection is consistent with U.S. conservation objectives.

The prospects for continued improvements in the technology, especially in overall centrifuge machine performance, leading to overall reductions in the cost of separative work by a factor of two in the next 10 to 15 years, are very good. The low costs achievable with the advanced centrifuge, as well as the sharply escalating cost of power used in the diffusion plants, indicate that it will become economically attractive to replace current diffusion plant capacity with the advanced centrifuge technology. Progress in the AIS processes will, of course, influence the extent of the role that gas centrifuge will play.

We recommend that DOE:

(a) Continue with the first 2.2 million SWU increment of the gas centrifuge program. Review this effort to minimize the cost of this increment without foreclosing the option for the additional 6.6 MSWU. The construction schedule of the 6.6 MSWU/yr. sections of the plant should be adjusted in accordance with AGC and AIS technology progress and relative marginal SWU costs from gaseous diffusion.

(b) Continue the Advanced Centrifuge development program, with high priority.

## 4.4 Proliferation

The AIS processes are at early stages of development (i.e., research programs) and have produced only gram quantities of product, whereas the gas centrifuge technology is operating abroad commercially and in this country in prototype form. This together with the fact that the AIS processes involve the marriage of several high technologies, makes them unlikely avenues for proliferation now by any except very advanced countries.

All AIS processes seem capable of modification for HEU production. Assuming one or more of the AIS processes are successfully developed and deployed, whether they will add significantly to the "baseline" risk is difficult to assess at this time and must be subject to continued scrutiny.

We recommend that the AIS program treat as a central design problem the development of criteria, designs, and procedures to minimize the risks of proliferation as the AIS processes mature. Ideally, development of AIS should not significantly increase the risk of proliferation.

## 4.5 DOE Organization

For many years, the enrichment enterprise has been operated to the extent possible as an independent business and costs of AIS R&D are included in the enterprise's financial plan. The Panel recommends that, to facilitate the making of long-term business decisions, all of the advanced uranium enrichment research and development be under the same overall DOE management organization, either in Resource Applications or any independent administrative cost center which is established.

About $2 billion annually flows to the U.S. Treasury from the sale of enrichment services. This income stream cannot be preserved for the future without a credible public plan for maintaining and expanding enrichment capacity.

Current plans are to ask for legislation to put the enrichment enterprise on a revolving fund basis so that operating costs will not require annual budgeting and appropriation as part of the regular Federal budget. It would be far better if the enterprise were made an entirely independent self-financing agency (like TVA) so that the R&D and capital addition costs could be administered independent of unrelated federal budget constraints.

While the relative organizational placement of advanced research and production in any organization can be open to much debate, the current DOE situation appears to be principally the result of history. The uranium enrichment enterprise is located in the Office of Resource Applications and is conducted on a revenue-cost basis, though its funding is still required to go through the normal Federal budget process. This includes operation of the Gaseous Diffusion complex and construction of the Gas Centrifuge Enrichment Plant, i.e., production functions. This office also manages some $65 million annually of centrifuge development.

All other aspects of advanced isotope separation are managed in the Office of Nuclear Energy where an R&D program of some $80 million annually is conducted at four principal locations. In total, the research and development is from 12-15 percent of annual sales of enrichment services.

The enrichment-budgets are determined on an annual basis in a process that trades enrichment budget with other DOE budget items. However, all enrichment costs are ultimately recovered from the sale of SWUs to utilities whereas the other DOE items are supported by federal taxes. The enrichment budgets should be separated from this process and judged on a business basis consistent with the usual practices of a business concerning return on investment, productivity, economics, growth capability, etc. The research aspects of the work should be given sufficient identity so as not to be lost or relegated to low priority status, and should be subject to staff review by the Office of Energy Research.

## 4.6 Other Isotope Separation Methods

We recommend that periodic assessment of other isotope separation methods be continued, giving some attention to new ideas and new technology. At the same time, care should be taken to avoid excessive commitments of funds or resources to methods which do not have clear or substantial advantage over the current production processes. The French chemical exchange process, although potentially competitive with gaseous diffusion, does not appear to have the very good promise of the favored U.S. AIS processes; funding of efforts on chemical exchange should not be allowed to impact significantly the laser and plasma AIS programs.

# APPENDIX A

# ADVANCED TECHNOLOGY PROCESS DESCRIPTIONS

## A.1 Advanced Gas Centrifuge

The Advanced Gas Centrifuge Program is aimed at decreasing new plant SWU costs by about 50 percent in constant dollars over a period of about 15 years by further development of the machines already in production for the Portsmouth GCEP. Improvements are to be achieved through increases in speed (facilitated by materials and design developments), modifications of size and geometry, increased internal flow efficiencies, and reduction in machine manufacturing costs and plant costs.

## A.2 AVLIS

### A.2.1 General

In the atomic vapor laser isotope separation (AVLIS), a supersonic beam of atomic uranium vapor is produced. The ground-state atoms are excited by a sequence of 3 visible photons from dye lasers operating at wavelengths $\lambda_{1a}$, $\lambda_2$, and $\lambda_3$. The metastable atoms are first excited by a fourth laser of wavelength $\lambda_{1b}$, then by $\lambda_2$ and $\lambda_3$. The final photon absorbed by the uranium atom produces an autoionizing state, which rapidly decays into a uranium ion and a free electron. The autoionizing state is used because the optical excitation cross section to that state is much larger than the photoionization cross section to the continuum. The narrow bandwidth in each of the selected transitions means that each of the laser wavelengths must be accurate to within one part in $10^6$ before enrichment can occur.

Negligible excitation of U-238 atoms occurs when the lasers are optimized to excite U-235. Because of the high selectivity, enrichment from 0.2 percent to 3.2 percent can be achieved in a single step; thus the atomic vapor process is particularly suitable for stripping U-235 from depleted uranium tails. Naturally, with appropriate plant design parameters, the atomic vapor process can also enrich natural uranium.

The uranium ions are collected from the photo-plasma by electrostatic or electromagnetic collection on plates. Guard plates are used to prevent the unionized uranium atoms of the beam from striking the product collector plates. The uranium vapor density must not be so high that appreciable charge exchange occurs during the acceleration of the U-235 to the collecting plates. Care must also be taken to ensure that the sputtering of uranium atoms from the collector plates does not seriously degrade the isotopic selectivity of the process.

### A.2.2 Livermore

The Livermore scheme is based on the use of high-repetition-rate copper-vapor lasers to pump the dye lasers. These lasers emit at blue wavelength which does not degrade the dye laser medium as rapidly as flashlamp radiation does. However, many stages of copper-vapor-laser amplification are required, and large modularized copper-vapor lasers are now beginning to be tested at Livermore. Significant scaling up of these lasers remains to be done, since discharge stability and lifetime may be a problem.

The physical dimensions of the module are set by the photon absorption cross sections and by the pulse repetition rates from the lasers. These require collector dimensions (along the uranium beam) of some ten centimeters and vapor path lengths (along the laser beams) of many meters; the effective optical path must be increased by reflecting the laser beam through the vapor several times. Care must be taken to ensure that diffraction and inhomogeneities in the index of refraction do not degrade the spatial quality of the beam. These, and more fundamental questions regarding the propagation physics, must be examined experimentally with vapor pathlengths approaching 100 meters.

The Livermore AVLIS program has done a particularly careful job of delineating and exploring the important physics of the AVLIS process. Major technical issues are the LLNL uranium collectors, which would be very attractive if they prove to be successful; the copper-vapor pump lasers, which have no history of use at high power in an industrial environment; and problems, such as sputtering and charge exchange, generic to operation of atomic vapor collectors. Finally, the Livermore program is just now coming to grips with many engineering issues which will be crucial in a successful isotope enrichment plant.

### A.2.3 JNAI

The JNAI plans call for batch processing of the collected uranium product on plates which are cooled to prevent melting of the uranium metal. The collector assembly must be replaced periodically through an air lock. The enriched uranium is removed from the collector plate by oxidation in a low temperature oven. The tails are removed as a block. A working vacuum interlock module has been tested at Richland.

Like Livermore, the JNAI process uses tunable dye lasers, but the lasers are pumped by flashlamps rather than by copper-vapor lasers. The flashlamp/dye-laser system is a well-tested, straightforward technology. It is fully integrated and it performs quite well. Dye solvent purification is handled in a continuous flow loop, and careful control of the process parameters minimizes dye degradation. The flashlamp-pumped dye laser has a pulse length of 1000 nsec, and intermediate states of somewhat longer radiative lifetimes than those used in the Livermore process are used to accommodate the longer pulses. The flashlamp pulsing rate of several hundred pulses per second requires large-scale multiplexing of the laser beams to achieve repetition rates in the multi-kilohertz range. As in the Livermore process, serious propagation questions remain to be examined with the full vapor path length, and generic collector issues must be resolved.

### A.3 MLIS

The molecular laser isotope separation process is based on photodissociation of gaseous $UF_6$ to solid $UF_5$, which can be extracted from the flow by a filter. Isotopically selective photodissociation is produced by strong vibrational excitation of the $\nu_3$ mode of U-$235F_6$ with a carefully-tuned 16-micron laser, followed by dissociation with an ultraviolet laser at 308 nm. The first step is the isotopically selective one. Photodissociation of $UF_6$ by ultraviolet light (unaided by infrared) is not intrinsically isotopically selective, but the cross-section for dissociation of vibrationally excited $UF_6$ has been shown to be much higher than for unexcited $UF_6$.

The $UF_6$ must be cooled to narrow the absorption spectrum of $UF_6$ sufficiently to produce isotope selectivity. This is accomplished (while retaining gas densities many orders of magnitude above the equilibrium vapor pressure) by rapidly expanding the $UF_6$ in a carrier gas ($N_2$,A,etc.) through a nozzle to supersonic speeds. The supersonic region is illuminated with both 16-micron and 308-nm radiation to produce the solid enriched product as a fine powder. The gas is recompressed through a diffuser; solid product is then removed, and the tails stream can be pumped to another stage. The $UF_5$ product can be refluorinated for further enrichment or extracted from the process, as is done routinely in the gaseous diffusion plant.

As presently conceived, a 9 MSWU/Yr MLIS plant would yield product at an assay of 4.85% and tails at .097%. The $UF_6$ flow system is entirely based on conventional technology and a continuous flow loop has been operating at UCC-ND for several years. A filter system for removal of the $UF_5$ precipatate has been recently demonstrated at UCC-ND. The technology for the basic $UF_6$ flow system, $UF_5$ product removal, staging and refluorination is very low risk and not an issue in assessing the commercial viability of the process. In addition, the fact that the MLIS process is conceived as a staged system offers some flexibility for handling different missions, including tails stripping, with the same plant.

The major technology developments required for the MLIS process to be commercially viable involve the two laser systems and associated optics. The 16-micron laser system is based on well-established $CO_2$ laser technology. Repetitively pulsed $CO_2$ lasers, of the type required for MLIS, have not attained the level of commercial development, but the high-PRF, low energy-per-pulse system required for MLIS appears to offer no major technological challenge and should be achievable with low risk with a reasonable development program.

The 308-nm UV laser system, however, will require substantial development to achieve low-cost, reliable devices. The laser is a preionized discharge-pumped xenon chloride excimer laser which has been operated as a laboratory device at the single-pulse energies and efficiencies required for the process. Achieving long-life, reliable devices is, however, made difficult by the chemically reactive gases used in the laser and by the very short discharge current risetimes required for efficient operation. Spark gaps are currently used to achieve these risetimes, but the lifetime of spark gaps is well below the $10^9$ shot life desired. Present commercial thyratrons have the demonstrated life capability but are not capable of achieving the needed risetimes. Both development paths are being pursued. The ultimate commercial viability of this process depends critically upon laser reliabilities and lifetimes.

### A.4 Plasma Separation Process (PSP) - TRW

The PSP operates at high vacuum within a 20,000 gauss magnetic field produced by a superconducting coil. Uranium vapor is generated from uranium metal. U-235 ions are then selectively energized in cyclotron orbits by a radiofrequency (127 kHz) electric field, while nonresonant U-238 ions attain much less cyclotron energy. The electric field is produced by radiofrequency current in conductors bounding the plasma.

The large-diameter orbits of the U-235 intersect collector plates aligned parallel to the magnetic field, while the small-diameter U-238 orbits pass through to the tails plate or are caught on tabs.

The vapor source, drive coil and collector have all operated together in a 0.5 m bore magnet with plasma diameter 20 cm by 1.3 m long. Because in this small module many atoms escape without being ionized, and for other adverse scaling reasons, only indications of overall performance are available.

According to TRW, all technical questions should be resolved and full performance demonstrated on the 1-m bore magnet in April 1982. It is therefore not necessary to commit to a 4-meter bore magnet until the 1-meter is successfully demonstrated and the PSP selected for AIS deployment.

# APPENDIX B

## PRODUCTION ALTERNATIVES

The panel examined a number of alternative schedules. The principal ones affecting strategy are shown below:

### B.1 DOE Planning Base

The DOE has several SWU projection scenarios bounded by low and high cases corresponding to 250 and 350 gigawatts of nuclear power by the year 2000. Both include modest military requirements as well. There is relatively little difference in annual rates in this decade (e.g., 22.5 vs. 24.0 million SWU's in 1985 and 27.5 vs. 30.3 million SWU's in 1990). The assumptions used in computing the data shown in Tables B.1-B.9 are described in Section B.5. Table B.1 shows the current base scenario for 250 gigawatts. Current U.S. enrichment contracts, domestic and foreign, support the equivalent of approximately 300 gigawatts of nuclear power by the year 2000. The base case of 250 gigawatts implies some cancellation of contracts, the 350 gigawatt case would represent about five new nuclear units under contract a year beginning about 1990. An important thing to note is the large increase in power required, which is covered by firm power contracts through 1992. Planning and investment may be required to assure that such is available. Table B.5 shows the same data for the 350 gigawatt case.

### B.2 Slowdown of the Centrifuge

The panel endorses the strategy of slowing the later stages of the centrifuge program, as reflected in current DOE planning, accepting the need to increase power consumption further in early years in order to build inventory to satisfy later demand. The scenario is that of Table B.2 (B.5 for 350 gigawatts). Subsequent centrifuge programming can be considered in future years to be dependent on then-current estimates of demand, cost of power, progress in AGC and economic projections of AIS. If the centrifuge were delayed indefinitely, the total electric power requirements of over 6 gigawatts or about 60 billion kilowatt hours per year would be required well into the 1990's or until AIS could take over the growing demand and begin to replace gaseous diffusion. See Table B.2 (B.6 for 360 GW) and compare to Table B.1 (or B.5). With the possible continuing differential escalation in costs of power, over operating costs, this could prove to be a very costly choice.

### B.3 Acceleration Potential

It is probable that both the centrifuge and the AIS programs can be accelerated. Tables B.3 and B.4 (respectively) present a realistic acceleration potential the panel believes could be accomplished without excessive cost penalties (Tables B.7 and B.8 describe the 350 gigawatt case). Acceleration of AIS depends on success in development as well

## Table B.1

250 GWe AIS FY 95 (4.4 MM SWU/yr/yr) "Base Case"
6B GCEP (IV) (2042B)

| FY | SWU Supply 1/ GDP | GCEP | AIS | GDP Power MW | Elec. Req'd Billions kWh | Tails Assay wt.% | Feed Req'd MM kgU | Product Stockpile MT kgU 3.2% | MM SWU at 0.2%Ts | Feed Stockpile MM kgU | Govt. Feed Sales (-)/ Purchases (+) MM kgU | Govt. Cost MM $ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | (millions of SWU) |  |  |  |  |  |  |  |  |  |  |  |
| 80 | 11.3 |  |  | 2974 | 26.0 | .20 | 15.6 | 7.03 | 33.4 | 29.8 |  | 1002 |
| 1 | 9.6 |  |  | 2585 | 22.6 | .2104 | 7.7 | 6.58 | 31.2 | 30.8 |  | 933 |
| 2 | 12.5 |  |  | 3226 | 28.3 | ↓ | 17.2 | 5.81 | 27.6 | 35.6 |  | 1367 |
| 3 | 14.9 |  |  | 3860 | 33.8 |  | 20.2 | 4.81 | 22.8 | 34.9 |  | 1571 |
| 4 | 16.7 |  |  | 4446 | 38.9 |  | 23.1 | 3.99 | 19.0 | 33.6 | -0.8 | 1648 |
| 85 | 19.3 |  |  | 4992 | 43.7 |  | 26.1 | 3.41 | 16.2 | 30.7 | -0.7 | 1813 |
| 6 | 21.4 |  |  | 5579 | 48.9 |  | 28.3 | 3.29 | 15.6 | 27.6 | -1.1 | 1938 |
| 7 | 22.8 |  |  | 6030 | 52.8 |  | 31.2 | 3.03 | 14.4 | 24.9 | -2.5 | 1926 |
| 8 | 22.2 | 0.4 |  | 5820 | 51.0 | .2124 | 30.1 | 2.77 | 13.1 | 23.5 | -2.3 | 2034 |
| 9 | 21.8 | 1.1 |  | 5703 | 50.0 | .1986 | 28.2 | 2.61 | 12.4 | 22.7 | -1.6 | 2131 |
| 90 | 23.1 | 3.6 |  | 6120 | 53.6 | ↓ | 33.2 | 2.80 | 13.3 | 19.4 | -2.2 | 2194 |
| 1 | 18.7 | 5.8 |  | 4857 | 42.5 |  | 30.6 | 2.45 | 11.6 | 19.5 | -1.8 | 1903 |
| 2 | 20.6 | 8.3 |  | 5349 | 46.9 | .2039 | 36.0 | 2.50 | 11.8 | 15.9 | -2.1 | 1977 |
| 3 | 19.4 | 10.6 |  | 5001 | 43.8 | .1992 | 36.6 | 2.54 | 12.0 | 11.6 | -2.9 | 1805 |
| 4 | 19.2 | 12.7 |  | 4966 | 43.5 | .1955 | 38.3 | 2.61 | 12.4 | 6.8 | -3.2 | 1844 |
| 95 | 22.3 | 13.8 |  | 5848 | 51.2 | .2008 | 44.1 | 3.61 | 17.1 | 0 | 0 | 2494 |
| 6 | 24.0 | ↓ | 4.4 | 6411 | 56.2 | .2071 | 34.1 | 2.66 | 12.6 | 16.9 | -3.8 | 2242 |
| 7 | 22.5 |  | 8.8 | 5925 | 51.9 | .1965 | 41.9 | 2.75 | 13.1 | 19.4 | -3.9 | 2163 |
| 8 | 20.6 |  | 13.2 | 5337 | 46.8 | .1896 | 41.3 | 2.70 | 13.2 | 23.5 | -3.7 | 2097 |
| 9 | 18.0 |  | 17.6 | 4718 | 41.3 | .1834 | 42.6 | 2.83 | 13.4 | 26.0 | -4.4 | 1889 |
| 2000 | 15.8 |  | 22.0 | 4209 | 36.9 | .1779 | 44.4 | 2.92 | 13.9 | 27.2 | -4.9 | 1740 |
|  |  |  |  |  | 910.6 |  | 650.8 |  |  |  |  |  |

Table B.2

250 GWe　　AIS FY 95 (4.4 MM SWU/yr/yr)
2B GCEP (IV)　(2057B)

"Without Full GCEP"

| FY | SWU Supply<br>GDP | <br>GCEP | <br>AIS<br>(millions of SWU) | GDP Power MW | Elec. Req'd Billions KWh | Tails Assay wt.% | Feed Req'd MM KgU | Product Stockpile<br>MM KgU 3.2% | <br>MM SWU at 0.2%Xw | Feed Stockpile MM kgU | Govt. Feed Sales (-)/ Purchases (+) MM kgU | Govt. Cost MM $ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 11.3 | | | 2974 | 26.0 | .20 | 15.6 | 7.03 | 33.4 | 29.8 | | 1002 |
| 1 | 9.6 | | | 2585 | 22.6 | .2339 | 8.6 | 6.67 | 31.7 | 35.8 | | 933 |
| 2 | 13.2 | | | 3375 | 29.6 | ↓ | 19.3 | 6.16 | 29.2 | 32.6 | | 1395 |
| 3 | 15.2 | | | 3997 | 35.0 | ↓ | 22.0 | 5.35 | 25.4 | 30.2 | | 1597 |
| 4 | 17.3 | | | 4574 | 40.1 | ↓ | 25.5 | 4.83 | 22.9 | 26.4 | -0.8 | 1673 |
| 85 | 19.8 | | | 5115 | 44.8 | ↓ | 28.5 | 4.52 | 21.5 | 21.1 | -0.7 | 1788 |
| 6 | 21.8 | | | 5696 | 49.9 | ↓ | 30.8 | 4.67 | 22.2 | 15.6 | -1.1 | 1819 |
| 7 | 23.1 | | | 6113 | 53.5 | ↓ | 33.6 | 4.67 | 22.1 | 10.5 | -2.5 | 1770 |
| 8 | 20.9 | 0.4 | | 5430 | 47.6 | .2049 | 27.6 | 4.04 | 19.2 | 11.6 | -2.3 | 1610 |
| 9 | 22.5 | 1.1 | | 5927 | 51.9 | ↓ | 29.8 | 4.11 | 19.5 | 9.1 | -1.6 | 1815 |
| 90 | 23.6 | 2.6 | | 6265 | 54.9 | ↓ | 33.4 | 4.28 | 20.3 | 5.6 | -2.2 | 1815 |
| 1 | 19.9 | 3.0 | | 5124 | 44.9 | ↓ | 29.3 | 3.66 | 17.4 | 7.2 | -1.9 | 1539 |
| 2 | 23.2 | 3.4 | | 6146 | 53.8 | .2146 | 34.6 | 3.36 | 16.0 | 5.5 | -2.3 | 1795 |
| 3 | 24.4 | ↓ | | 6572 | 57.6 | .2232 | 37.5 | 3.31 | 15.7 | 1.2 | -3.3 | 1886 |
| 4 | 24.9 | ↓ | | 6778 | 59.4 | .2297 | 39.1 | 3.15 | 15.0 | 0 | -0.9 | 2392 |
| 95 | 25.3 | ↓ | | 6959 | 61.0 | .2360 | 40.1 | 3.07 | 14.6 | 0 | 0 | 2642 |
| 6 | 25.2 | ↓ | 4.4 | 6914 | 60.6 | .2339 | 39.1 | 2.66 | 12.6 | 3.8 | -4.3 | 2138 |
| 7 | 24.7 | ↓ | 8.8 | 6710 | 58.8 | .2265 | 44.0 | 2.75 | 13.0 | 2.5 | -4.5 | 2137 |
| 8 | 24.4 | ↓ | 13.2 | 6557 | 57.4 | .2168 | 43.2 | 2.77 | 13.1 | 4.9 | -4.2 | 2217 |
| 9 | 23.6 | ↓ | 17.6 | 6289 | 55.1 | .2074 | 44.4 | 2.84 | 13.5 | 7.0 | -4.9 | 2129 |
| 2000 | 22.4 | ↓ | 22.0 | 5886 | 51.6 | .1998 | 45.9 | 2.92 | 13.8 | 8.5 | -5.3 | 2032 |
| | | | | | 1016.1 | | 671.9 | | | | | |

## Table B.3

250 GW-
BB GCLP (IV) Accelerated    AIS FY 95 (4.4 MM SWU/yr/yr) (2071B)    "Accelerated GCLP"

| FY | SWU Supply GDP (millions of SWU) | SWU Supply GCLP (millions of SWU) | SWU Supply AIS (millions of SWU) | GDP Power MW | Elec. Req'd Billions kWh | Tails Assay wt.% | Feed Req'd MM kgU | Product Stockpile MM kgU 3.2% | Product Stockpile MM SWU at 0.2%Xw | Feed Stockpile MM kgU | Govt. Feed Sales (-)/ Purchases (+) MM kgU | Govt. Cost MM $ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 11.3 | | | 2974 | 26.0 | .20 | 15.6 | 7.03 | 33.4 | 29.8 | | 1002 |
| 1 | 9.6 | | | 2585 | 22.6 | .2128 | 7.4 | 6.55 | 31.1 | 37.1 | | 1063 |
| 2 | 12.7 | | | 3275 | 28.7 | ↓ | 17.1 | 5.79 | 27.5 | 36.0 | | 1555 |
| 3 | 15.0 | | | 3905 | 34.2 | ↓ | 19.9 | 4.76 | 22.6 | 35.7 | | 1736 |
| 4 | 16.9 | | | 4488 | 39.3 | ↓ | 22.9 | 3.95 | 18.7 | 34.6 | -0.8 | 1793 |
| 85 | 19.5 | | | 5032 | 44.1 | ↓ | 25.7 | 3.34 | 15.8 | 32.1 | -0.7 | 1971 |
| 6 | 21.5 | | | 5618 | 49.2 | ↓ | 27.9 | 3.18 | 15.1 | 29.5 | -1.1 | 2049 |
| 7 | 23.1 | 1.1 | | 6058 | 53.1 | ↓ | 32.3 | 3.16 | 15.0 | 25.7 | -2.5 | 2083 |
| 8 | 19.8 | 2.8 | | 5065 | 44.4 | .2087 | 29.6 | 2.84 | 13.5 | 24.7 | -2.3 | 1932 |
| 9 | 18.0 | 4.6 | | 4654 | 40.8 | .1898 | 26.7 | 2.50 | 11.9 | 25.4 | -1.6 | 1959 |
| 90 | 20.3 | 7.5 | | 5212 | 45.7 | ↓ | 33.3 | 2.78 | 13.2 | 22.0 | -2.2 | 2040 |
| 1 | 14.8 | 10.3 | | 3782 | 33.1 | ↓ | 30.2 | 2.43 | 11.5 | 22.3 | -1.6 | 1661 |
| 2 | 17.0 | 12.9 | | 4292 | 37.6 | .1932 | 35.5 | 2.50 | 11.8 | 18.7 | -1.9 | 1604 |
| 3 | 16.5 | 13.8 | | 4422 | 38.7 | .1944 | 36.3 | 2.54 | 12.0 | 14.5 | -2.8 | 1520 |
| 4 | 18.3 | ↓ | | 4770 | 41.8 | .1931 | 38.2 | 2.61 | 12.4 | 9.8 | -3.1 | 1696 |
| 95 | 21.9 | ↓ | | 5727 | 50.2 | .1990 | 43.6 | 3.54 | 16.8 | 0 | -3.1 | 2046 |
| 6 | 23.8 | ↓ | 4.4 | 6354 | 55.7 | .2054 | 34.4 | 2.66 | 12.6 | 16.0 | -3.7 | 2229 |
| 7 | 22.2 | ↓ | 8.8 | 5822 | 51.0 | .1950 | 41.7 | 2.75 | 13.1 | 18.1 | -3.9 | 2136 |
| 8 | 20.0 | ↓ | 13.2 | 5167 | 45.3 | .1878 | 41.2 | 2.77 | 13.2 | 21.5 | -3.7 | 2050 |
| 9 | 17.5 | ↓ | 17.6 | 4604 | 40.3 | .1821 | 42.6 | 2.84 | 13.5 | 23.4 | -4.4 | 1857 |
| 2000 | 15.5 | ↓ | 22.0 | 4106 | 36.0 | .1768 | 44.3 | 2.92 | 13.9 | 24.4 | -4.8 | 1709 |
| | | | | | 857.8 | | 646.4 | | | | | |

Table B.4

250 GWe AIS FY 90 (4.4 MM SWU/yr/yr)
2B GCEP (IV) (2050B)

"Accelerated AIS"

| FY | SWU Supply | | | GDP Power MW | Elec. Req'd Billions kWh | Tails Assay wt.% | Feed Req'd MM kgU | Product Stockpile | | Feed Stockpile MM kgU | Govt. Feed Sales (-)/ Purchases (+) MM kgU | Govt. Cost MM $ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GDP (Billions of SWU) | GCEP | AIS | | | | | MM kgU 3.2% | MM SWU at 0.2%Xw | | | |
| 80 | 11.3 | | | 2974 | 26.0 | .20 | 15.6 | 7.03 | 33.4 | 29.8 | | 1002 |
| 1 | 9.6 | | | 2585 | 22.6 | .2153 | 7.5 | 6.56 | 31.2 | 37.0 | | 933 |
| 2 | 13.1 | | | 3344 | 29.3 | ↓ | 17.7 | 5.89 | 28.0 | 35.3 | | 1389 |
| 3 | 15.1 | | | 3968 | 34.8 | ↓ | 20.3 | 4.91 | 23.3 | 34.5 | | 1592 |
| 4 | 17.2 | | | 4547 | 39.8 | ↓ | 23.5 | 4.19 | 19.9 | 32.8 | -0.8 | 1668 |
| 85 | 19.7 | | | 5087 | 44.6 | ↓ | 26.3 | 3.66 | 17.4 | 29.7 | -0.7 | 1783 |
| 6 | 21.7 | | | 5672 | 49.7 | ↓ | 28.4 | 3.58 | 17.0 | 26.6 | -1.1 | 1878 |
| 7 | 23.0 | | | 6095 | 53.4 | ↓ | 31.1 | 3.32 | 15.8 | 24.0 | -2.5 | 1911 |
| 8 | 21.1 | 0.4 | | 5484 | 48.0 | .2069 | 28.0 | 2.76 | 13.1 | 24.6 | -2.3 | 1850 |
| 9 | 22.6 | 1.1 | | 5961 | 52.2 | ↓ | 30.2 | 2.88 | 13.7 | 21.8 | -1.6 | 2119 |
| 90 | 23.6 | 2.6 | | 6287 | 55.1 | ↓ | 33.7 | 3.08 | 14.6 | 17.9 | -2.2 | 2165 |
| 1 | 16.2 | 3.0 | 4.4 | 4323 | 37.9 | .1904 | 28.4 | 2.43 | 11.5 | 19.9 | -1.7 | 1720 |
| 2 | 17.7 | 3.4 | 8.8 | 4641 | 40.7 | .1934 | 35.5 | 2.50 | 11.9 | 16.4 | -1.9 | 1781 |
| 3 | 14.6 | ↓ | 13.2 | 3732 | 32.7 | .1838 | 35.7 | 2.54 | 12.0 | 12.4 | -2.6 | 1497 |
| 4 | 12.3 | ↓ | 17.6 | 3185 | 27.9 | .1787 | 37.3 | 2.61 | 12.4 | 8.0 | -2.9 | 1372 |
| 95 | 16.8 | ↓ | 22.0 | 4465 | 39.1 | .1875 | 46.6 | 4.21 | 20.0 | 0 | 0 | 2226 |
| 6 | 21.1 | ↓ | 26.4 | 5484 | 48.0 | .1934 | 29.9 | 2.66 | 12.6 | 27.8 | -0.4 | 2141 |
| 7 | 17.2 | ↓ | 30.8 | 4560 | 39.9 | .1833 | 41.0 | 2.75 | 13.1 | 33.1 | -3.7 | 1923 |
| 8 | 12.5 | ↓ | 35.2 | 3215 | 28.2 | .1757 | 40.4 | 2.77 | 13.2 | 37.7 | -3.4 | 1597 |
| 9 | 9.6 | ↓ | 39.6 | 2592 | 22.7 | .1653 | 41.8 | 2.84 | 13.5 | 40.3 | -4.2 | 1368 |
| 2000 | 8.2 | ↓ | 44.0 | 2283 | 20.0 | .1633 | 43.4 | 2.92 | 13.9 | 42.1 | -4.6 | 1276 |
| | | | | | 792.6 | | 642.3 | | | | | |

Table B.5

"Base Case"

750 GWe	AIS FY 95 (4.4 MM SWU/yr/yr)
88 GCEP (IV)	(20140)

| FY | SWU Supply<br>GDP | <br>GCEP | <br>AIS | GDP Power MW | Elec. Req'd billions kWh | Tails Assay wt. % | Feed Req'd MM kgU | Product Stockpile<br>MM kgU 3.2% | <br>MM SWU at 0.2%w | Feed Stockpile MM kgU | Govt. Feed Sales (-)/ Purchases (+) MM kgU | Govt. Cost* MM $ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (millions of SWU) | | | | | | | | | | | |
| 80 | 11.3 | | | 2974 | 26.0 | .20 | 15.6 | 7.03 | 33.4 | 29.8 | | 1002 |
| 1 | 9.6 | | | 2585 | 22.6 | .2100 | 7.7 | 6.58 | 31.3 | 36.7 | | 933 |
| 2 | 14.5 | | | 3712 | 32.5 | ↓ | 19.9 | 6.26 | 29.7 | 32.9 | | 1458 |
| 3 | 16.1 | | | 4309 | 37.7 | ↓ | 21.9 | 5.39 | 25.6 | 31.3 | | 1657 |
| 4 | 18.7 | | | 4866 | 42.6 | ↓ | 25.8 | 4.70 | 22.3 | 30.0 | | 1826 |
| 85 | 21.0 | | | 5445 | 47.7 | ↓ | 28.3 | 4.16 | 19.8 | 27.4 | | 1977 |
| 6 | 22.6 | | | 5936 | 52.0 | ↓ | 30.5 | 3.62 | 17.2 | 27.9 | | 2138 |
| 7 | 23.6 | | | 6269 | 54.9 | ↓ | 32.5 | 3.40 | 16.1 | 27.4 | | 2276 |
| 8 | 24.2 | 0.4 | | 6498 | 56.9 | ↓ | 34.4 | 3.31 | 15.7 | 26.8 | | 2457 |
| 9 | 24.5 | 1.1 | | 6630 | 58.1 | ↓ | 35.1 | 3.11 | 14.7 | 26.8 | | 2528 |
| 90 | 24.8 | 3.6 | | 6746 | 59.1 | ↓ | 39.0 | 3.01 | 14.3 | 25.4 | -0.6 | 2531 |
| 1 | 23.9 | 5.8 | | 6391 | 56.0 | ↓ | 40.8 | 2.83 | 13.4 | 25.4 | -1.1 | 2412 |
| 2 | 24.7 | 8.3 | | 6601 | 58.5 | .2272 | 46.5 | 2.87 | 13.6 | 21.9 | -1.9 | 2358 |
| 3 | 24.8 | 10.6 | | 6727 | 58.9 | .2298 | 49.7 | 2.97 | 14.1 | 17.3 | -2.7 | 2294 |
| 4 | 24.6 | 12.7 | | 6643 | 58.2 | .2221 | 50.7 | 3.14 | 14.9 | 12.0 | -3.0 | 2318 |
| 95 | 25.0 | 13.8 | | 6840 | 59.9 | .2204 | 54.2 | 3.30 | 16.0 | 5.9 | -3.4 | 2292 |
| 6 | 25.5 | ↓ | 4.4 | 7020 | 61.5 | .2355 | 55.1 | 3.23 | 15.3 | 7.9 | -4.8 | 2226 |
| 7 | 25.0 | ↓ | 8.8 | 6847 | 60.0 | .2223 | 57.4 | 3.32 | 15.8 | 7.4 | -4.4 | 2320 |
| 8 | 24.8 | ↓ | 13.2 | 6732 | 59.0 | .2155 | 59.3 | 3.42 | 16.2 | 7.3 | -5.0 | 2285 |
| 9 | 24.6 | ↓ | 17.6 | 6636 | 58.1 | .2101 | 62.2 | 3.56 | 16.9 | 6.2 | -6.3 | 2140 |
| 2000 | 24.3 | ↓ | 22.0 | 6523 | 57.1 | .2042 | 63.6 | 3.65 | 17.3 | 6.5 | -6.3 | 2180 |
| | | | | | 1077.3 | | 830.2 | | | | | |

*Includes costs of feed purchases (+) or sales (-), power, operation, R&D, and capital.

## Table B.6

"Without Full GCEP"

350 GWe AIS FY 95 (4.4 MM SWU/yr/yr)
20 GCEP (IV) (20130)

| FY | SWU Supply<br>GDP (millions of SWU) | GCEP | AIS | GDP Power MW | Elec. Req'd billions kWh | Tails Assay wt.% | Feed Req'd MM kgU | Product Stockpile MM kgU 3.2% | MM SWU at 0.2xxw | Feed Stockpile MM kgU | Govt. Feed Sales (-)/ Purchases (+) MM kgU | Govt. Cost* MM $ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 11.3 | | | 2974 | 26.0 | .20 | 15.5 | 7.03 | 33.4 | 29.8 | | 1002 |
| 1 | 9.6 | | | 2585 | 22.6 | .2294 | 8.4 | 6.65 | 31.5 | 36.1 | | 933 |
| 2 | 19.9 | | | 5147 | 45.1 | ↓ | 28.3 | 7.63 | 36.2 | 23.8 | | 1714 |
| 3 | 21.9 | | | 5718 | 50.1 | ↓ | 30.9 | 8.15 | 38.7 | 13.3 | | 1905 |
| 4 | 23.1 | | | 6130 | 53.7 | ↓ | 33.1 | 8.57 | 40.7 | 4.7 | | 2050 |
| 85 | 23.9 | | | 6395 | 56.0 | ↓ | 32.0 | 8.56 | 40.6 | 0 | | 2103 |
| 6 | 24.4 | | | 6571 | 57.6 | ↓ | 32.7 | 8.29 | 39.3 | ↓ | | 2116 |
| 7 | 24.7 | | | 6691 | 58.6 | ↓ | 33.7 | 8.17 | 38.8 | ↓ | | 2186 |
| 8 | 24.9 | 0.4 | | 6803 | 59.6 | ↓ | 35.2 | 8.11 | 38.5 | ↓ | | 2171 |
| 9 | 25.2 | 1.1 | | 6908 | 60.5 | ↓ | 36.2 | 7.98 | 37.9 | ↓ | | 2223 |
| 90 | 25.4 | 2.6 | | 7000 | 61.4 | ↓ | 39.1 | 7.79 | 37.0 | ↓ | | 2252 |
| 1 | 25.0 | 3.0 | | 6809 | 59.6 | .2362 | 41.3 | 7.48 | 35.5 | 0.4 | -1.4 | 2051 |
| 2 | 25.4 | 3.4 | | 6989 | 61.2 | .2430 | 43.4 | 6.81 | 32.4 | 0.9 | -2.3 | 2012 |
| 3 | 25.5 | ↓ | | 7060 | 61.8 | .2662 | 47.2 | 6.03 | 28.6 | 0 | -3.2 | 2011 |
| 4 | 25.5 | ↓ | | ↓ | ↓ | .2662 | 47.2 | 5.01 | 23.9 | 0 | -3.7 | 2062 |
| 95 | 25.5 | ↓ | | ↓ | ↓ | .2770 | 49.2 | 3.70 | 17.9 | 0.2 | -4.0 | 2096 |
| 6 | ↓ | ↓ | 4.4 | ↓ | ↓ | .2770 | 56.8 | 3.23 | 15.3 | 0 | +0.4 | 2824 |
| 7 | ↓ | ↓ | 8.8 | ↓ | ↓ | .2743 | 61.1 | 3.32 | 15.8 | ↓ | +4.2 | 3476 |
| 8 | ↓ | ↓ | 13.2 | ↓ | ↓ | .2645 | 64.7 | 3.42 | 16.2 | ↓ | +0.3 | 2993 |
| 9 | ↓ | ↓ | 17.6 | ↓ | ↓ | .2559 | 67.3 | 3.55 | 16.9 | ↓ | -3.0 | 2590 |
| 2000 | ↓ | ↓ | 22.0 | ↓ | ↓ | .2457 | 68.3 | 3.65 | 17.3 | ↓ | -5.2 | 2344 |
| | | | | | 1166.4 | | 873.6 | | | | | |

*Includes costs of feed purchases (+) or sales (-), power, operation, R&D, and capital.

Table B.7

350 GWe
88 GCEP (IV) Accelerated    AIS FY 95 (4.4 MM SWU/yr/yr)    "Accelerate GCEP"
(208 GW)

| FY | SWU Supply |  |  | GDP Power MW | Elec. Req'd Billions kWh | Tails Assay wt.% | Feed Req'd MM kgU | Product Stockpile |  | Feed Stockpile MM kgU | Govt. Feed Sales (-)/ Purchases (+) MM kgU | Govt. Cost MM $ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | GDP | GCEP | AIS |  |  |  |  | MM kgU 3.2% | MM SWU at 0.2%xw |  |  |  |
|  | (millions of SWU) |  |  |  |  |  |  |  |  |  |  |  |
| 80 | 11.3 |  |  | 2974 | 26.0 | .20 | 15.6 | 7.03 | 33.4 | 29.8 |  | 1002 |
| 1 | 9.6 |  |  | 2585 | 22.6 | .2296 | 8.4 | 6.65 | 31.6 | 30.1 |  | 1063 |
| 2 | 13.7 |  |  | 3487 | 30.5 | ↓ | 19.6 | 6.21 | 29.5 | 32.5 |  | 1595 |
| 3 | 15.5 |  |  | 4101 | 35.9 | ↓ | 22.0 | 5.28 | 25.1 | 30.9 |  | 1773 |
| 4 | 17.8 |  |  | 4671 | 40.9 | ↓ | 25.7 | 4.50 | 21.4 | 30.0 |  | 1928 |
| 85 | 20.2 |  |  | 5229 | 45.8 | ↓ | 28.5 | 3.91 | 18.6 | 26.9 |  | 2088 |
| 6 | 22.1 |  |  | 5779 | 50.6 | ↓ | 31.2 | 3.39 | 16.1 | 26.7 |  | 2212 |
| 7 | 23.5 | 1.1 |  | 6172 | 54.1 | ↓ | 35.3 | 3.53 | 16.8 | 23.4 |  | 2409 |
| 8 | 20.9 | 2.8 |  | 5309 | 47.2 | .2033 | 31.1 | 3.04 | 14.4 | 26.0 |  | 2285 |
| 9 | 22.6 | 4.6 |  | 5892 | 51.6 | ↓ | 34.9 | 2.95 | 14.0 | 26.2 |  | 2420 |
| 90 | 23.6 | 7.5 |  | 6243 | 54.7 | ↓ | 40.0 | 3.19 | 15.1 | 23.9 | -0.6 | 2463 |
| 1 | 19.8 | 10.3 |  | 5077 | 44.5 | ↓ | 38.7 | 2.82 | 13.4 | 25.2 | -0.7 | 2144 |
| 2 | 22.6 | 12.9 |  | 5669 | 49.7 | .2063 | 45.9 | 3.03 | 14.4 | 21.3 | -1.5 | 2044 |
| 3 | 23.7 | 13.8 |  | 6310 | 55.3 | .2121 | 49.0 | 3.26 | 15.5 | 16.4 | -2.3 | 2106 |
| 4 | 24.5 | ↓ |  | 6624 | 58.0 | .2187 | 51.4 | 3.59 | 17.0 | 10.2 | -2.9 | 2228 |
| 95 | 25.0 | ↓ |  | 6819 | 59.7 | .2244 | 53.3 | 3.74 | 17.7 | 4.8 | -3.3 | 2300 |
| 6 | 25.4 | ↓ | 4.4 | 7000 | 61.3 | .2311 | 52.8 | 3.28 | 15.6 | 9.8 | -4.7 | 2238 |
| 7 | 25.1 | ↓ | 8.8 | 6855 | 60.0 | .2214 | 57.0 | 3.32 | 15.8 | 9.6 | -4.4 | 2326 |
| 8 | 24.8 | ↓ | 13.2 | 6735 | 59.0 | .2136 | 59.1 | 3.42 | 16.2 | 9.3 | -4.9 | 2294 |
| 9 | 24.5 | ↓ | 17.6 | 6616 | 58.0 | .2068 | 61.8 | 3.55 | 16.9 | 7.8 | -6.2 | 2148 |
| 2000 | 24.2 | ↓ | 22.0 | 6486 | 56.8 | .2007 | 63.3 | 3.65 | 17.3 | 7.5 | -6.2 | 2184 |
|  |  |  |  |  | 1022.4 |  | 824.4 |  |  |  |  |  |

## Table B.8

150 GW   AIS FY 90 (4.4 MM SWU/yr/yr)   "Accelerate AIS"
2b GCEP (IV)   (2074B)

| FY | SWU Supply 1/<br>GDP | GCEP | AIS<br>(millions of SWU) | GDP Power MW | Elec. Req'd Billions kWh | Tails Assay wt.% | Feed Req'd MM kgU | Product Stockpile<br>MM kgU 3.2% | MM SWU at 0.2%Xw | Feed Stockpile MM kgU | Govt. Feed Sales (-)/ Purchases (+) MM kgU | Govt. Cost MM $ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 11.3 | | | 2974 | 26.0 | .20 | 15.6 | 7.03 | 33.4 | 29.8 | | 1002 |
| 1 | 9.6 | | | 2585 | 22.6 | .2237 | 8.0 | 6.61 | 31.4 | 30.4 | | 933 |
| 2 | 14.7 | | | 3779 | 33.1 | ↓ | 20.5 | 6.36 | 30.2 | 32.0 | | 1470 |
| 3 | 16.3 | | | 4371 | 38.3 | | 22.6 | 5.58 | 26.5 | 29.7 | | 1668 |
| 4 | 19.0 | | | 4923 | 43.1 | | 26.7 | 5.01 | 23.8 | 27.5 | | 1836 |
| 85 | 21.2 | | | 5505 | 48.2 | | 29.1 | 4.57 | 21.7 | 24.0 | | 1940 |
| 6 | 22.7 | | | 5980 | 52.4 | | 31.3 | 4.12 | 19.6 | 23.6 | | 2069 |
| 7 | 23.7 | | | 6297 | 55.2 | | 33.2 | 3.98 | 18.9 | 22.4 | | 2253 |
| 8 | 24.3 | 0.4 | | 6519 | 57.1 | | 35.2 | 3.97 | 18.9 | 21.0 | | 2346 |
| 9 | 24.6 | 1.1 | | 6642 | 58.2 | | 35.8 | 3.84 | 18.2 | 20.3 | | 2465 |
| 90 | 24.8 | 2.6 | | 6758 | 59.2 | | 38.5 | 3.61 | 17.1 | 19.5 | -0.6 | 2469 |
| 1 | 22.0 | 3.0 | 4.4 | 5774 | 50.6 | .2014 | 37.6 | 3.08 | 14.6 | 21.8 | -0.7 | 2243 |
| 2 | 21.8 | 3.4 | 8.8 | 5706 | 50.0 | .2059 | 43.0 | 2.87 | 13.6 | 20.4 | -1.3 | 2145 |
| 3 | 21.5 | ↓ | 13.2 | 5607 | 49.1 | .1999 | 47.3 | 2.97 | 14.1 | 16.6 | -2.0 | 2107 |
| 4 | 19.4 | | 17.6 | 5005 | 43.8 | .1932 | 48.7 | 3.20 | 15.2 | 11.8 | -2.3 | 1970 |
| 95 | 22.9 | | 22.0 | 6037 | 52.9 | .2014 | 60.2 | 4.86 | 23.1 | 0 | -0.8 | 2576 |
| 6 | 24.2 | | 26.4 | 6506 | 57.0 | .2076 | 43.7 | 3.23 | 15.3 | 25.2 | -4.1 | 2322 |
| 7 | 23.1 | | 30.8 | 6106 | 53.5 | .1970 | 55.1 | 3.32 | 15.8 | 29.4 | -3.8 | 2331 |
| 8 | 21.7 | | 35.2 | 5678 | 49.7 | .1906 | 57.0 | 3.42 | 16.2 | 32.6 | -4.3 | 2199 |
| 9 | 20.1 | | 39.6 | 5192 | 45.5 | .1852 | 59.7 | 3.55 | 16.9 | 33.6 | -5.6 | 1935 |
| 2000 | 18.4 | | 44.0 | 4782 | 41.9 | .1802 | 61.3 | 3.65 | 17.3 | 34.2 | -5.6 | 1872 |
| | | | | | 967.4 | | 810.1 | | | | | |

Table B.9

Summary of Results

| | | | Electricity Required, billions kWh | | | | Feed Required, MM kgU | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 350 GWe | | 250 GWe | | 350 GWe | | 250 GWe | |
| | GCEP | AIS | Cum. 1980-2000 | Δ Base | Cum. 1980-2000 | Δ Base | Cum. | Δ Base | Cum. | Δ Base |
| "Base Case" | 8B (IV) | FY 95 | 1077.3 | - | 910.6 | - | 830.2 | - | 650.8 | - |
| "Without Full GCEP" | 2B (IV) | FY 95 | 1166.4 | +89.1 | 1016.1 | +105.5 | 873.6 | +43.4 | 671.9 | +21.1 |
| "Accel. GCEP" | 8B (IV) Accel. | FY 95 | 1022.4 | -54.9 | 857.8 | -52.8 | 824.4 | -5.8 | 646.4 | -4.4 |
| "Accel. AIS" | 2B (IV) | FY 90 | 987.4 | -89.9 | 792.6 | -118.0 | 810.1 | -20.1 | 642.3 | -8.5 |

| | | | Cumulative Enterprise Cost<br>(millions of 1980 $; FY 1980 thru FY 2010) | |
|---|---|---|---|---|
| | GCEP | AIS | 350 GWe | 250 GWe |
| "Base Case" | 8B (IV) | FY 95 | 69097 | 53841 |
| "Without Full GCEP | 2B (IV) | FY 95 | 70855 | 54285 |
| "Accel. GCEP" | 8B (IV) Accel. | FY 95 | 69023 | 53908 |
| "Accel. AIS" | 2B (IV) | FY 90 | 66948 | 52254 |

as accelerated funding. Acceleration of GCEP is simply a matter of schedule and funding changes.

The centrifuge program has been slowed down several times already and can still recover much of the original schedule. Some acceleration of the first 2.2 million SWU increment is recommended by the panel, but not the entire program at this time. Acceleration of the AIS program might involve funding two of the AIS approaches in order to improve confidence that a practical system might evolve. Only one AIS element (PSP) proposed a schedule improved to the extent shown on the table. The panel does not recommend acceleration of any AIS element until one of them resolves its critical uncertainties.

The integrated effects of the various options on 20 year electrical energy and uranium feed requirements, together with 30 year cumulative enterprise costs, are summarized in Table B.9.

## B.4 Implications of Choice

The factors which are adjusted to optimize the diffusion plant to meet current and projected demands most efficiently and with high reliability are:

- Enriched product or SWU inventory
- Tails inventory and tails assay
- Tails refeed or recycle
- Normal feed inventory
- Normal feed procurement, amount, and cost
- Plant operating plan, mix of facilities and plants
- Power
    - o Contracts in effect
    - o Costs now and projected for future
    - o Costs and timing of contract changes
- Annual costs to DOE for operations, current and projected costs optimized over 30-year period.

However, if one wishes to optimize the total uranium enrichment endeavor, large uncertainties in projecting costs of the various inputs and progress in the various advanced technologies make the procedure quite difficult. Judgmental inputs are necessary, and planning must be consistent with the prudent protection of reasonable future options, not solely for any maximum, minimum, or favored case. Also, there are practical limitations such as with short term budget objectives and short-time large changes in power level. Further, changing national policies can have a substantial impact on the demand for enriched uranium, both for domestic and foreign power reactors as well as in the weapons or military programs.

To determine the effect of changing the mix and timing for integrating advanced isotope separation into the overall enrichment enterprise, Oak Ridge has calculated a large number of cases "optimized" for the particular process mix and timing assumptions which constrain the procedure. Cases presented by Oak Ridge show overall enterprise cost totals and by year from 1980 to 2010 for enrichment demands to support 250 GW and 350 GW nuclear power levels by the year 2000 for each of the following technology mixes:

- Planned GD and GCEP (base) (27 MMSWU and 9 MSWU)
- Base + AIS (8 MSWU) in 1990
- Base + AIS in 1995
- GD Plant + AIS in 1990
- GD Plant + AIS in 1995
- GD + 2 MSWU GCEP + AIS (1990)
- GD + 2 MSWU GCEP + AIS (1995)

The significant output of these studies is also shown in Tables B.1 to B.9. Current U.S. enrichment contracts, domestic and foreign, are the equivalent of approximately 300 gigawatts of nuclear power by the year 2000. The base case of 250 gigawatts implies some cancellation of contracts, the 350 gigawatt case would represent about five new nuclear units under contract a year beginning about 1990.

In addition, at this Panel's request, sensitivity to the following considerations were run:

- Higher power cost (35 mils vs. Base 23 mils)
- Lower demand (208 GW - domestic moratorium)
- Discount rate (7.5, 10, 15 percent)
- Constrained power (4300 MWe)
- Early technology cost growth (AIS cost Base, 2X, 5X)
- GCEP deployment rate (2.2, 4.4, 6.6, 8.8 MMSWU)
- AIS introduction date (1990, 1993, 1995)

This Panel's conclusions and recommendations concerning mix and timing of upgrade are in large part based on the results of these studies. Some particularly noteworthy findings were:

a. The high-demand case (350 GW) can lead to very high peaks in DOE annual costs and feed requirements in the late 1990's if GCEP and AIS are not included.

b. These discontinuities are not apparent for the 250 GW or 208 GW demand cases and are greatly reduced for the 250 GW case if 2 MSWU GC is installed.

c. Averaged over the 20-year period 1980-2000 for both high and low demands, cost/SWU is reduced by 2-30 percent from the various mixes. The largest swing (30 percent reduction) is from introduction of AIS in 1990 vs. 1995). Forward cost would of course be reduced much more with the deployment of larger amounts of AIS.

d. For the 350 GW case, introduction of full GCEP plus AIS in 1990 (vs. 1995) implies a savings of about 2000 MW of electrical power for about a decade from the base case. With

2 MSWU GCEP the savings would be about half that. The savings would be about 1000 MW for the 250 GW case.

e. Two to three times as many SWUs would be needed to enrich the current tails inventory with any of the advanced mixes. It could be economically attractive if the projected costs of AIS are achieved (after all GDP production has been displaced).

f. Product inventory requirements are met by all the choices of mix and timing displayed here.

g. The most significant additional findings of the sensitivity analysis were that:

   - A 4300 MW power constraint would greatly impact optimization of the enrichment process for the 350- and 250 GW case, but probably not be significant for the 208 GW case. In any case, early introduction of GCEP and AIS would greatly ease the problem.
   - Cumulative enterprise investment varied by less than 5 percent between cases where AIS is introduced in 1990 at a cost of 2X or 5X baseline cost, if base is reached by 1995.

## B.5 Input Assumptions

### B.5.1 GCEP Input Assumptions

Input assumptions for GCEP include the one-year slip as scheduled in the President's amended budget. The one-year slip was applied to the GCEP Project Master Schedule, Issue 3, of October 1979. On this basis, following the slip, Building-Operational dates would be June 1988 for Building 1, October 1989 for Building 2, and June 1994 for Building 8.

Costs of the Set III GCEP, prior to the schedule slip and in 1980 dollars, were assumed to be $5.1 billion for eight buildings and $2.75 billion for two buildings, with $900 million of these costs unrecoverable should the decision be made in 1980 to terminate the GCEP. Following the slip, capital costs were assumed to be $5.3 billion for eight buildings and $2.85 billion for two buildings. Since no detailed cost schedules were available for the slipped construction schedules, cost schedules were estimated by suitable adjustment of available data on costs prior to the slip. Operation of the completed GCEP was assumed to require 135 MW of electrical power and $188 million/year of other operation costs.

Implementation of Set IV technology was assumed to be possible on a schedule which would permit Set IV to be the initial fill of Buildings 3 through 8, while simultaneously retrofitting Buildings 1 and 2 in FY 1989, FY 1990, and FY 1991. The retrofitted two-building GCEP would be achieved at an estimated total cost of $3.07 billion and would have an estimated capacity of 3.4 million SWU/yr. The completed eight-building Set IV GCEP would be achieved at an estimate total cost of $5.41 billion and have an estimated capacity of 13.8 million SWU/yr.

Demands - (Assumptions Provided by DOE/OURE) Extend through FY 2010 with FY 2000 levels as follows:

| | Year 2000 U.S. - Supported GWe Nuclear | | |
|---|---|---|---|
| | U.S. | Foreign | Total |
| Mid | 200 | 150 | 350 |
| Low | 150 | 100 | 250 |

Campaign - FY 1980 - FY 2010.

GDP Power - Power levels optimized within contract limits through FY 1984 and an upper limit of 7,060 MW thereafter. Other diffusion operating costs were treated as a function of power up to 4630 MW and constant thereafter.

Power Cost - 23 mills/kWh in 1980 dollars; differential escalation three percent p.a. through FY 1990, 1-1/2 percent p.a. thereafter.

In the optimization, a marginal cost of 18 mills/kWh is used (all to escalation).

Feed Cost - $115/kgU as $UF_6$ in 1980 dollars; differential escalation 1.5 percent p.a. Mid (350 GWe) demand, 1.0 percent p.a. Low (250 GWe) demand.

Feed Sale Rules - DOE sells up to a limit of 50 percent of demand above a floor of 23,077 MTU/yr Mid (350 GWe) demand, and a floor of 16,484 MTU/yr Low (250 GWe) demand.

The separative performance estimated for the Set IV machine can be obtained by a combination of speed and internal flow efficiency improvement. It is anticipated that the Set IV centrifuge technology will use only components and subassemblies that have been tested in the Gas Centrifuge Development Program by 1980.

### B.5.2 AIS Deployment

The deployment rate for a new plant with AIS technology was assumed to be 4.4 million SWU/yr/yr with first production starting at end-of-FY 1990 or end-of-FY 1995.

AIS costs (for an 8.8 MWSU/yr plant) were adapted from the generic case of $27/SWU, $720 million capital, including 18 percent interest during construction, $120 million/year operating costs in 1979 dollars plus $50 million technical support. Costs were escalated to the 1980 dollar starting point and spread over a 5 year construction spending pattern, putting interest at 10 percent back in to result in about 20 percent I.D.C.

### B.5.3 Other Input Assumptions

The following are general input assumptions which are not related to specific choice of process.

Financial Assumptions - 1980 dollars, 10 percent p.a. discount rate, capital written off over 25 years to arrive at a credit for remaining useful life for each plant at the end of the 31 year campaign, to subtract from the enterprise capital cost. All new plant costs accumulate I.D.C. during the construction spending years at 10 percent until the plant comes on stream.

Tails Assay - Operating tails assay 0.20 percent in 1980, optimized thereafter. Toll enricher transaction tails assay 0.20 percent through 1990, equal to operating tails thereafter but not to exceed 0.25 percent.

Enriched Product Stockpile - Minimum of 90 days requirements plus five million SWU strategic reserve.

# APPENDIX C
# CHARTER LETTER

**Department of Energy**
**Washington, D.C. 20585**

May 1, 1980

Mr. Solomon J. Buchsbaum
Chairman
Energy Research Advisory Board
Bell Laboratories
Crawford Corner Road
Holmdel, New Jersey 07733

Dear Sol:

The Advanced Isotope Separation Technology Program has been concentrating on three alternative separation processes for some time. Recently a fourth privately sponsored separation process program has been proposed to DOE. The overall strategy of the Advanced Isotope Separation Program is currently under review.

The three programs under DOE sponsorship are the Atomic Vapor Laser Isotope Separation (AVLIS) process at Lawrence Livermore Laboratory, The Molecular Laser Isotope Separation (MLIS) process at Los Alamos Scientific Laboratory and the Plasma Separation Process (PSP) at TRW Inc. The fourth privately sponsored R&D project at Jersey Nuclear Avco Isotopes (JNAI) utilizes technology which is similar to the AVLIS process.

The Under Secretary has requested that ERAB convene a Study Group to review DOE's Advanced Isotope Separation Strategy and the role of Jersey Nuclear AVCO Isotopes in that program. Specifically ERAB is requested to review the AVLIS, PSP, MLIS and JNAI processes with respect to:

- o Overall Advanced Isotope Separation Program Strategy
- o Current technology state of the art
- o Future risks, benefits and costs associated with implementation of a particular AIS technology.

I understand that ERAB will appoint an Ad Hoc Study Group to be chaired by Louis Roddis. The ERAB findings will be utilized to assist the Department in the development of an Advanced Isotope Separation Program Plan. The recommendations and findings of the Board should be forwarded to me by September 30.

Sincerely,

Ed Frieman

Edward A. Frieman
Director of Energy Research

# APPENDIX D
## BRIEFINGS

| | |
|---|---|
| June 1980 | DC: Program Overview |
| 20 June 1980 | Oak Ridge: Union Carbide briefings on existing separation technologies and UCC participation in AIS |
| 14 July 1980 | Richland, Washington: JNAI AVLIS Program |
| 15-16 July 1980 | LLL: LLL AVLIS Program |
| 16 July 1980 | Los Angeles: Rocketdyne MLIS Laser Development |
| 17 July 1980 | Los Angeles: TRW PSP Program |
| 28-29 July 1980 | LASL: LASL MLIS Program<br>AGS Program by DoE and VCC. |
| 24 September 1980 | DC: Panel Meeting: Classified Report Preparation |
| 10 October 1980 | DC: Panel Meeting: Review Deletions from Classified Version |

# APPENDIX E
# GLOSSARY

AGC - Advanced Gas Centrifuge. The generic term for a variety of methods for improving the efficiency of gas centrifuge processes. Some of these improvements are being implemented now; some (see SET IV) are in technology development stages; an some, which might lower centrifuge product cost to the \$40-50/SWU range, are still in the research stage.

AIS - Advanced Isotope Separation. Used in this report to comprise Molecular Laser Isotope Separation, Atomic Vapor Laser Isotope Separation, and the Plasma Separation Processes.

ASWU - (See SWU).

AVLIS - Atomic Vapor Laser Isotope Separation. In this process, atomic uranium vapor is produced by bombarding a feed tray with an energetic electron beam. Vapor expansion cools excitations resulting from the high sublimation temperature. It then passes into the region where the U-235 atoms are selectively excited, then ionized by visible radiation from dye lasers. The enriched ionized product is collected on biased collector plates, and the tails flow through the system to a final collector plate. For details, see Appendix A.

Enrichment - Raising the U-235 fraction in any sample of uranium. Natural uranium is 0.7% U-235; light-water-reactor fuel has been enriched to about 3%.

GC,GCEP - Gas Centrifuge, Gas Centrifuge Enrichment Plant. Scheme, which after long development has now reached the commercialization stage, for enriching uranium by using the different weights of U-235 and U-238 (combined with fluorine as $UF_6$ gas) to separate them in a large centrifuge. The first U.S. plant (of 2.2 million annual SWU capacity is currently under construction.

GD,GDP - Gaseous Diffusion, Gaseous Diffusion Plant. Scheme, developed during World War II and the standard enrichment process ever since, which uses the isotopic difference in the rate of permeation (by $UF_6$ gas) of porous membranes to achieve enrichment. GD operation requires far more power than GC, or any of the AIS technologies.

HEU - Highly Enriched Uranium. Expressed as % U-235. Usually over 20%.

LEU - Low Enriched Uranium usually in the 2-4% U-235 range.

MLIS - Molecular Laser Isotope Separation. In this process uranium hexafluoride ($UF_6$) is first vibrationally excited by an infrared laser which selectively excites the molecules containing U-235. Then an ultraviolet laser photodissociates one of the fluorine atoms from the excited molecule, producing enriched $UF_5$ which precipitates out of the gas flow as a solid. For details see Appendix A.

PSP - Plasma Separation Process. In this process uranium ions produced from a solid feed source are injected along an axial magnetic field in a cylindrical vacuum chamber. Radio-frequency energy is injected, tuned to excite U-235 more efficiently than U-238. The higher velocity of the U-235 ions gives them larger orbits around the field lines as they move down the cylinder; appropriately spaced collectors at the end can thus remove more U-235 than U-238 from the flow, providing enrichment. For details, see Appendix A.

SET IV - AGC improvements expected to be implemented in the late 80s.

Stripping - The process of enriching the tails of a previous enrichment process or stage.

SWU - Separative Work Unit. The standard measure of enrichment process work in kilograms. ASWU (Annual rate of SWU capacity) is a measure of plant capacity. Current price is about $100 per kg SWU. Per kg of U-235 contained in the product, for a plant fed with natural (0.7% U-235) and discharging tails at 0.2% U-235, the SWU content is as follows:

98% U-235, 275 SWU/kg U-235;
20% U-235, 228 SWU/kg U-235;
3.3% U-235, 156 SWU/kg U-235;
2.0% U-235, 110 SWU/kg U-235.

Tails - The depleted product (that is, what remains after the enriched product is removed) of an enrichment process or stage. Expressed as % of U-235 content.

# APPENDIX F

## BIBLIOGRAPHY

| | | |
|---|---|---|
| 1. | Energy Research Advisory Board<br>Advanced Isotope Separation<br>Ad Hoc Study Group<br>Molecular Laser Isotope Separation<br>Program Review (LASL) | AP-DO-80:181<br>7/28/80<br>S/RD |
| 2. | Plasma Separation Process<br>Development Program<br>Overview (TRW) | TRWA-29160-444<br>7/17/80<br>S/RD |
| 3. | General Commentary on the<br>Advanced Isotope Separation Program | CLYA 80-152<br>7/16/80<br>S/RD |
| 4. | JNAI - LIS Program<br>Program Review (LLL) | XJA-EL-P-006<br>7/80<br>Confidential<br>Proprietary |
| 5. | Advanced Isotope Separation<br>Program Review (LLL) | CLYA 80-148<br>7/15-16/80<br>S/RD |
| 6. | Enrichment Planning Studies on<br>AIS/AGC Progress Report of<br>June 20, 1980 (UCC-ND) | K/TD-398<br>6/20/80<br>S/RD |
| 7. | Energy Research Advisory Board<br>Advanced Isotope Separation<br>Ad Hoc Study Group<br>Review of Oak Ridge Programs<br>Vol. III - Progress Report on<br>Process Economic Assessments and<br>Enrichment Enterprise Calculations (UCC-ND) | K/ET-533<br>6/19-20/80<br>S/RD |
| 8. | Energy Research Advisory Board<br>Advanced Isotope Separation<br>Ad Hoc Study Group<br>Review of Oak Ridge Programs<br>Vol. IV - Classified and Selected<br>Additional Charts From Uranium<br>Enrichment Overview (Vol. I) and<br>Advanced Isotope Separation Program<br>Review (Vol. II) (UCC-ND) | K/ET-534<br>6/19-20/80<br>S/RD |

| | | |
|---|---|---|
| 9. | Energy Research Advisory Board<br>Advanced Isotope Separation<br>Ad Hoc Study Group<br>Vol. V - Status Report on<br>Economic Assessment of<br>JNAI Process (UCC-ND) | K/ET-575<br>7/29/80<br>S/RD |
| 10. | Energy Research Advisory Board<br>Advanced Isotope Separation<br>Ad Hoc Study Group<br>Vol. VII - Advanced Gas<br>Centrifuge Overview (UCC-ND) | K/ET-577<br>7/29/80<br>S/RD |
| 11. | Letter to Roddis from Davis RE:<br>More Systematic Quantitative<br>Answers Than Those Given<br>Verbally During the Meeting<br>(LLL) | CLYA 80-155<br>7/24/80<br>S/RD |
| 12. | Energy Research Advisory Board<br>Advanced Isotope Separation<br>Ad Hoc Study Group<br>Review of Oak Ridge Programs<br>Vol. II - Advanced Isotope Separation<br>Program Review (UCC-ND) | K/ET-532<br>6/19-20/80<br>UNCLASSIFIED |
| 13. | Energy Research Advisory Board<br>Advanced Isotope Separation<br>Ad Hoc Study Group<br>Vol. VI - Additional Enrichment<br>Enterprise Calculations (UCC-ND) | K/ET-576<br>7/29/80<br>OUO |
| 14. | Enrichment Planning Studies on<br>AIS/AGC Progress Report of<br>June 20, 1980 - Additional<br>Sensitivity Cases | K/TD-398<br>Addendum 1<br>6/24/80<br>OUO |
| 15. | LS-15 Laser System<br>Status Report<br>(Rockwell International) | 7/25/80<br>UNCLASSIFIED |
| 16. | Diffraction Grating Beam Combiners<br>(Rockwell International) | 7/23/80 |
| 17. | Report of Ad Hoc Study Group on<br>Methods of Uranium Isotope Separation<br>(ORO) | ORO-762<br>12/27/79<br>C/NSI |
| 18. | Report of Ad Hoc Study Group on<br>Methods of Uranium Isotope Separation<br>(ORO) | ORO-760<br>1/24/79<br>S/RD |

| | | |
|---|---|---|
| 19. | FY 1979 Advanced Isotope Separation Economic Assessment and Status Report (UCC-ND) | K/OA-4700<br>9/30/79<br>S/RD |
| 20. | Letter to Davis from Stern RE: An Experimental Limit on Uranium Dimer Abundances and Some Consequences (LLL) | CLYA 79-61<br>3/21/79<br>C/RD |
| 21. | Report of Advisory Panel for Review of the Laser Isotope Separation Program | 2/2/77<br>C/RD |
| 22. | ASE Calculations (LASL) | 7/15/80<br>C/RD |
| 23. | Letter to Emmett from Davis RE: Superfluorescent Limit on Metal Vapor Scalability (LLL) | JID 75-190<br>10/31/75<br>UNCLASSIFIED |
| 24. | Report of the Ad Hoc NSC Panel on Laser Applications to Energy R&D<br>I. Laser Fusion<br>II. Laser Isotope Separation | S/RD<br>Draft 2/28/74 |
| 25. | PSP Near Term Performance Scaling (TRW) | TRWA-29160-0589<br>7/25/80<br>S/RD |
| 26. | Summary - Program Plans Status, Objectives, and Options (LASL) | AP-DO-80:186<br>7/28/80<br>UNCLASSIFIED |
| 27. | Manson Benedict, Abraham S. Berman, Jacob Bigeleisen, Edward T. Gerry, Jack E. Powell, and Paul R. Vanstrum, Appendix Report of Ad Hoc Study Group on Methods of Uranium Isotope Separation, United States Department of Energy (ORO) | ORO-761<br>8/21/79<br>S/RD |
| 28. | "Nuclear Proliferation and Civilian Nuclear Power," Report of the Nonproliferation Alternative System Assessment Program, Executive Summary (DOE/NE) | DOE/NE-ool<br>6/80<br>UNCLASSIFIED |
| 29. | "Laser Isotope Separation: Proliferation Risks and Benefits," Volume I, Report of the Laser Enrichment Review Panel of Jersey Nuclear Avco Isotopes, Inc. | 2/27/79 |

| | | |
|---|---|---|
| 30. | "Interim Report on the Proliferation Implications of Enrichment Technologies (U)," (Revision 2) by P. Melling, T. Albert, and J. Walkosh, Science Applications, Inc. | SAI/LJ 78:1551<br>12/20/78<br>S/RD |
| 31. | "IAEA Safeguards Considerations for U.S. Preconceptual Design of Laser Uranium - Isotope Separation Plans (U)," Draft, Prepared by D. M. Gordon, J. R. Lemley and R. C. Fuller, Brookhaven National Laboratory | BNL<br>3/13/79<br>S/RD |
| 32. | "Safeguards Concepts for Advanced Isotope Separation Facilities (U)," by D. B. Smith, D. Stirpe, and J. P. Shipley, LASL | W-4/79-612<br>11/79<br>S/RD |
| 33. | "Final Report on Molecular Isotope Separation Proliferation Resistance Study, (U)," The Garrett Corporation | LIS-CP-46<br>12/79<br>S/RD |
| 34. | "The Proliferation Implications of Uranium Enrichment Technologies (U)," Review Draft, Volume II, by W. P. Melling, et al, Science Applications, Inc. | SAI/JL DC#80:1238<br>7/22/80<br>S/RD |
| 35. | 1981 DOE Authority Hearings Before the Subcommittee on Energy Research and Production of the Committee on Science and Technology, U.S. House of Representatives, 96th Congress, 2nd Session, February 5, 7, 12, 13, and March 4, 1980, #114, Vol. 2. | U.S. House of Rep.<br>1980<br>UNCLASSIFIED |
| 36. | Uranium Enrichment 1979 Annual Report, U.S. DOE (ORO) | ORO-773<br>UNCLASSIFIED |
| 37. | Gas Centrifuge Uranium Enrichment Plant Progress Reports, FY 1979. | |

# APPENDIX G
# CONFLICT LETTER

Department of Energy
Washington, D.C. 20585

Dear AIS Study Group Member:

As members of an Adhoc Study Group of the Energy Research Advisory Board we are serving without compensation (as does the ERAB itself) and as such are not considered Government employees. We therefore do not fall under the normal provisions of the conflict of interest statutes.

It is, however, the practice of the Energy Research Advisory Board to consider possible interest conflicts that might exist in members of study groups. In the interests of saving time I am setting forth below my understanding of the involvement in the specific area of advanced isotope separation of each member of the AIS Study Group. If I have not properly reflected any potential source of bias, please let me know so that the final draft of this letter can be transmitted as evidence of consideration of the problem. I believe the situation is as follows:

Louis H. Roddis - Has consulted with Exxon R&E Co. and LASL on other matters than isotope separation.
- Was member of Isotope Separation Review for Executive Office of President previously.

Dayton Clewell - No involvement.

Thomas B. Cochran - No involvement.

W. Kenneth Davis - Officer of Uranium Enrichment Associates, an activity which is no longer active in the gas diffusion plant area.
- Officer, Bechtel Power Corporation but not directly involved in any current isotope work.

Richard L. Garwin - Consultant to Los Alamos Scientific Laboratory Separation Program and has publicly supported the MLIS approach.
- Consultant (inactive) to Exxon Nuclear on proliferation aspects of isotope separation.

Edward T. Gerry - Formerly with AVCO, one of the members of Jersey Isotopes.
- Member of previous (1978) AIS review group.

William Happer - No involvement.

Henry K. Hebeler - Past President of Boeing Engineering and Construction Company, which has a division which manufactures certrifigues for uranium enrichment, but not now directly involved in that portion of the company.

Michael I. Gamble - Assistant to Mr. Hebeler, no involvement in isotope separation.

Gordon O. Moe - Secretary of previous review panel while in Executive Office of the President.

Richard Osgood - Worked in 1977 on MIT project to develop a 16 micron laser for LASL.

Paul R. Vanstrum - Officer of that section of the Union Carbide Corporation which is directly concerned in the development of the analysis of Uranium Isotope Separation.
- Entire operations performed for Federal Government in Government facilities.

Respectfully submitted,

Louis H. Roddis, Jr.

LHR/jtg